DOCUMENT RESUME

ED 337 134 IR 015 120

AUTHOR Hodes, Carol L.
TITLE The Induction, Use, and Effectiveness of Mental Imagery as an Instructional Variable: A Thesis in Curriculum and Instruction.
PUB DATE Aug 90
NOTE 171p.; Ph.D. Dissertation, Pennsylvania State University.
PUB TYPE Dissertations/Theses - Doctoral Dissertations (041) -- Tests/Evaluation Instruments (160)

EDRS PRICE MF01/PC07 Plus Postage.
DESCRIPTORS Analysis of Variance; *Cognitive Processes; College Students; Higher Education; Hypothesis Testing; *Imagery; Imagination; *Intermode Differences; *Memory; Pretests Posttests; Problem Solving; Psychological Studies; Questionnaires; Visualization

ABSTRACT

This dissertation presents the results of an investigation of visual mental imagery as a strategy hypothesized to increase the amount of interaction with content material and therefore the level of information processing and acquisition, and to assist information retrieval on posttests. Four treatments were used in a crossed, randomized two by two factorial design. The two independent variables were imagery instructions embedded in the text and visual illustrations related to the text. Instructional materials used were four versions of a 2,000-word script on the human heart (F. M. Dwyer, 1978). Dependent measures taken were a drawing test and three multiple-choice tests of 20 questions each, designed to measure factual learning, identification of parts, and comprehension learning. A post-treatment questionnaire assessed the subjects' perceptions of the effect of the imagery instructions and their use of imagery. Significant differences were noted on the ANOVA tests for many of the dependent measures, and both factors produced significant results on the drawing posttest. The group with the treatment containing both visuals and imagery consistently had the highest means for all test measures, while the group having text plus imagery had the lowest multiple-choice test score means of all groups. Among this sample, imagery was found to be a prominent cognitive process for the retention of information in all learning situations. Although it is not used exclusively to retain information, there is some evidence that imagery instructions interact with instructional visuals when embedded in text. Appendices contain the informed consent form and instructions to the subjects, the post-treatment questionnaire, pilot study data, experimental materials, criterion-referenced posttests, reliability coefficients, and the cell means of the dependent measures. (117 references) (Author/DB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

ED337134

The Pennsylvania State University

The Graduate School

Division of Curriculum and Instruction

THE INDUCTION, USE, AND EFFECTIVENESS OF MENTAL IMAGERY AS AN INSTRUCTIONAL VARIABLE

A Thesis in

Curriculum and Instruction

by

Carol L. Hodes

Submitted in Partial Fufillment
of the Requirements
for the Degree of

Doctor of Philosophy

August 1990

112 015120

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Carol L. Hodes

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

ABSTRACT

There is support in the research literature that the use of visual imagery facilitates learning and is heavily utilized both for problem solving and the retrieval of complex information. Visual mental imagery was investigated as a strategy hypothesized to increase the amount of interaction with the content material and therefore the level of information processing and acquisition, and to assist information retrieval on posttests. Four treatments were used in a completely crossed, completely randomized two by two factorial design. The two independent variables were imagery instructions embedded in the text and visual illustrations related to the text. The instructional material was a 2000-word script on the human heart and congruent criterion posttests developed by Dwyer (1978). Dependent measures taken were a drawing test, and three multiple-choice tests of 20 questions each, designed to measure factual learning, identification of parts, and comprehension learning, respectively. A posttreatment questionnaire assessed the subjects' perceptions of the effect of the imagery instructions and their use of imagery.

Significant differences were noted on the ANOVA tests for many of the dependent measures. Both factors produced significant results on the drawing posttest. The visual

illustration factor produced significant main effects on the identification test.

The group with the treatment containing both visuals and imagery consistently had the highest means for all test measures. The group having text plus imagery had the lowest multiple-choice test score means of all groups. Imagery instructions produced significantly higher drawing test and accretion time means. Heavy task use of imagery had a significant negative correlation with faster testing (retrieval) time; however, the self-reports of imagery use during the treatment showed a similar imagery use pattern among the groups.

Among this sample, imagery was found to be a prominent cognitive process for the retention of information in all learning situations. It is not used exclusively of other strategies to retain information during accretion. Also, there is some evidence that imagery instructions interact with instructional visuals when embedded in text. The function of imagery instructions is discussed.

TABLE OF CONTENTS

Page

LIST OF FIGURES vii

LIST OF TABLES viii

ACKNOWLEDGEMENTS ix

Chapter One INTRODUCTION 1

Introduction 1
Rationale 4
Nature of the Study 7
Need for the Study 8
Statement of the Problem and Experimental Questions 11
Hypotheses 13
Scope 14
Limitations of the Study 14
Definition of Terms. 15

Chapter Two REVIEW OF THE LITERATURE 17

Current Imagery Theories 17
Imagery Ability 19
Imagery and Cognition. 21
Imagery and Associative Learning 30
Facilitating Imagery 32
Learning Strategies. 35
Visual Illustrations in Text 36
Processing Text-Based Information. 37

Chapter Three METHOD 39

Sample 40
Procedure. 40
Independent Variables. 41
Treatments 43
Dependent Variables. 44
Research Evaluation. 47

Chapter Four RESULTS 49

Results of the ANOVA Tests 49
Hypothesis Testing 49
Post-Treatment Questionnaire Data 52
Further Discussion of Criterion Posttests. . . . 53
Interaction Between Independent Variables. . . . 55
Questionnaire Results 56

Imagery as a Dominant Strategy 56
Patterns of Imagery Use. 57

Chapter Five SUMMARY AND CONCLUSIONS 62

Results 63
Discussion 64
Conclusions 67
Implications for Instructional Design. 69
Discussion of Experimental Procedures and Limitations. 70
Recommendations for Future Research. 72

REFERENCES 74

Appendix A INFORMED CONSENT FORM AND INSTRUCTIONS TO THE SUBJECTS. 83

Appendix B POST-TREATMENT QUESTIONNAIRE 88

Appendix C PILOT STUDY DATA AND ITEM ANALYSIS 90

Appendix D EXPERIMENTAL MATERIALS 92

Appendix E CRITERION-REFERENCED POSTTESTS 146

Appendix F RELIABILITY COEFFICIENTS 157

Appendix G CELL MEANS OF DEPENDENT MEASURES 159

LIST OF FIGURES

Figure 1. Frequency Responses to Likert Items x Group. .58

Figure 2. Proportion of Imagery Used During the Task and as a Dominant Strategy. 59

LIST OF TABLES

Table 1. ANOVA Summary of Dependent Measures: Total Criterion, Drawing and Accretion Time 50

Table 2. ANOVA Results: Identification Test. 54

Table 3. Pearson Correlation Matrix 60

ACKNOWLEDGEMENTS

The author thanks Dr. Helene Anthony, Assistant Professor of Educational Psychology, for cooperating with this research project and allowing her students to participate as subjects. This research was funded by research awards from the College of Education Alumni Association and the Pi Lambda Theta Research Awards Committee.

Chapter One

INTRODUCTION

Introduction

Cognitive strategies are important for attending, learning, remembering, and thinking. Educators have only a limited understanding of these internally organized skills which are under learner control (Briggs, 1981). One such strategy, visual mental imagery, is hypothesized to play an essential role in many kinds of thinking and problem solving (Gagne, 1985; Farah, 1984, 1989a; Paivio, 1969; Pompi and Lachman, 1967; Shepard, 1978), and is considered to be one of the primary modes for representing information in memory (Bower and Hilgard, 1981). Horowitz (1983) gives the most basic definition of an image as "any thought representation that has a sensory quality" (p. 3). Kosslyn (1981) depicts images as transitory data structures in an analog spatial medium.

Imagery, which is generated internally, is the result of information processing. The perceptual system processes visual information about the world and the imaginal system uses similar interpretive processes. Imagery and perception have common functions for the construction of mental representations and processing spatial information, i.e. orientation and depth relationships, which are

important for learning. With both the perceived and the imagined, relationships can be inspected and transformed to determine pattern similarities to other stored information (Finke et al., 1989).

Images have various sensory qualities, but the quality of primary interest in this study is the subject's ability to construct and to visualize the image. As a type of mental construct, an image is a non-lexical internal analog representation linked to, or associated with, concrete objects or events (Gagne, 1985; Paivio, 1969). Such mental constructs, which have a mediational role in learning and problem solving, can be actively generated by individuals and increase the level of information processing (Shepard and Podgarny, 1978; Anderson, 1970; Paivio, 1969). Images are particularly useful for forming mental representations of information containing spatial, temporal relationships (Kosslyn, 1980; Pylyshyn, 1981). Pinker (1984) and Gagne (1985) consider imagery to be controlled and monitored by the individual through the executive processes. Gagne (1985) and Weinstein and Mayer (1986) further classify imagery as a type of elaboration strategy used by learners to construct both internal associations among information in working memory and external associations between new information and prior knowledge. Increased elaboration makes information more distinctive and unique (Eysenck, 1989).

Imaginal representations are unobservable and, therefore, may be difficult to investigate. Researchers can only observe the evidence of image formation (Shepard, 1978) and make inferences based on tightly reasoned theories.

There is evidence on recognition tests that imagery facilitates recall (Kulhavy & Swenson, 1975; Anderson & Kulhavy, 1972; Frost, 1972; Luria, 1969). In mnemonics, associative imagery was long thought to play a mediational role (Bower, 1969; Yates, 1966). Nonverbal mediators are important both in cognitive processes and as a type of nonverbal schema that facilitates verbal learning (Gagne, 1985; Travers, 1982; Paivio, 1969). Shepard (1966) realized the dependence upon imagery for the recall of specific information. For example, it is impossible to recall the number of windows in a house without first imaging the house. No verbal process alone is sufficient for the recall of this type of information.

Imagery instructions are a component of mnemonic strategies (Paivio, 1969). Instructions to form mental images may arouse verbal mediators, increase motivation or interest, or cause more effective use of other mediators or strategies. Thus, imagery instructions are an effective stimulus variable to facilitate the formation of associations.

Rationale

Due to the limited capacity of short-term memory, information processing can deteriorate when dealing with large quantities of information. Therefore, the task is to organize instruction for increased attention and encoding. Anderson (1970) states: "the chief problem for educational engineering is to discover how to alter the characteristics of instructional tasks so as to force students to do all of the processing required for learning" (p. 363).

Interest in the study of the use of imagery is not new, but learning theory has largely ignored the role of imagery as a cognitive strategy until the last two decades (Farah, 1984; Pylyshyn, 1981; Paivio, 1969; Shepard, 1978). Therefore, the research base in the area of imagery and cognition extends back only about 20 years. This may be in part due to the fact that images are often difficult to manage, since the precise content and quality may be known only to the subject. Psychological studies of human memory have focused on elements of verbal behavior (Bower & Hilgard, 1981). This does not mean that images are considered unimportant or nonexistent. Verbal processes are studied to gain basic knowledge about cognition, and the presence of imagery cannot be ignored. Paivio (1969) states that when dealing with cognitive processes, there is sufficient evidence that "implicit verbal processes are no less inferential than images" (p. 242). It is just as

logical to infer that an individual can use imaginal mental constructs as well as mental words to mediate verbal responses. Images are constructed in the working memory in part from long-term visual memory which stores information about the physical appearance of objects (Farah, 1984).

Mental images are thought to be specialized representations used for processing spatial, temporal information (Kosslyn, 1980). Such information is contained in a 2000-word text passage about the function of the human heart. In order to answer correctly comprehension questions on the congruent criterion-referenced posttest, Dwyer (1978) has stated that it is necessary to position objects in the "mind's eye" and "mentally simulate functions and movements"... (p. 46). Thus, the generation of images is required to understand fully many complex processes and procedures. Even though imaginal processes have been shown to enhance learning and memory tasks (Einstein et al., 1989), and are considered to be pervasive throughout reading (Long, 1986), imagery is thought to be an under used strategy in formal learning situations. In addition, the presence of visuals with text is hypothesized to arouse imaginal processes (Paivio, 1969). Thus, the use of visuals in combination with the imagery instructions may be important for learning, particularly when the information is spatial and temporal in nature.

The present study extends the work of previous

The present study extends the work of previous researchers in the areas of mental imagery and visual literacy, and departs from their work by using specifically derived imagery instructions as a stimulus variable. To attempt to induce imagery in the subjects, the imagery instructions were formulated as a result of an item analysis of pilot study data. This analysis determined specific area of learner difficulty with complex text-based information as measured on a validated criterion-referenced posttest. The posttest was designed to measure the learning of terminology (basic facts and definitions), part identification (heart structures) and comprehension (rules pertaining to heart function). Such specific imagery instructions should facilitate the achievement of these outcomes due to increased attention, selective perception, and encoding of the information. Although the eliciting questions and the resulting behavior are both of a verbal nature, the mediating mechanism is not (Paivio, 1969).

The present study also investigated potential interactions between the use of related visuals with the text and the imagery instructions variables. The presence of visuals arouses imaginal processes and facilitates the formation of associations. The search for an interaction is based on the work of Paivio who states that familiar, unambiguously labeled visuals evoke both concrete imagery and verbal encoding. The available verbal encoding is not

as likely to be used since an extra transformation is involved.

Nature of the Study

For many years, imagery has been recognized as a mental process that might influence analytical thinking and problem solving. In recent years, imagery has been recognized as a type of elaboration strategy that can facilitate semantic encoding and therefore learning (Mayer, 1985; Gagne, 1985). Di Vesta et al. (1971) conclude that imagery can be a stimulus variable, an information-processing variable, or a distinctive individual difference variable that is actually a strategy preference in adults. Imagery is believed to be used best by experts who have been shown to form mental representations during problem solving that are qualitatively superior to those of novices (Chi, Glaser & Rees, 1989). However, little is known about the use of imagery as an instructional variable and its use to optimize learning and retention of instructional material (Frost, 1972; Luria, 1969; Shepard & Podgarny, 1978).

The proposed research will investigate the use of mental imagery as a cued elaboration strategy. Having orienting and alerting functions, imagery instructions facilitate elaboration and organization, and activate specific propositional networks or schemata, which in turn

facilitate the encoding and integration of information. Additionally, specific instructions, when related to the content in the form of instructions to form mental images of the content, may result in deeper information processing and, therefore, more distinctive mental representations which enhance learning and achievement. Also, Paivio (1969) and Di Vesta et al. (1971) suggest that task concreteness interacts with the use of imagery.

No studies were found which investigated interactions between specific instructional objectives and the construction of mental images in an instructional setting. In addition, no studies were found which used imagery instructions that were specific to the text material to be learned. Imagery studies reported in the literature used very general imagery instructions (Anderson & Hidde, 1971; Kulhavy & Swenson, 1975; Anderson & Kulhavy, 1977; Carrier et al., 1977). Most of the reported research studies did not take measures to maintain the use of the strategy throughout the instruction, although some studies were found that gave general instructions to form images at the bottom of each page of the treatment (Kulhavy & Swenson, 1975) or after reading each paragraph (Evans, 1982).

Need for the Study

The purpose of this study is to gain basic knowledge about the effectiveness of the use of imagery on learning

and achievement with text-based instructional materials. Furthermore, it is not known if imagery can be induced or how it is used by learners with instructional material.

Although there is support that the use of imagery enhances learning, most research has been conducted with paired-associate learning (Di Vesta & Ross, 1971) or recognition and recall tasks (Frost, 1982). Several studies have used imagery as a cued strategy for processing instructional materials (Anderson & Kulhavy, 1972; Kulhavy & Swenson, 1975; Dillingofski, 1980; McIntosh, 1984). Although the data of McIntosh support the use of imagery for the recall of rules, it is not known if the use of imagery facilitates the learning of other specific types of information.

Studies similar to the present study were found that gave only general instructions to the subjects, simply including general imagery instructions as a preface before reading an instructional passage (Carrier et al., 1983; Anderson & Hidde, 1971; Anderson & Kulhavy, 1972; McDaniel & Kearney, 1984) or to form images before they turn the page (Kulhavy & Swenson, 1975). None of the instructions required constructing mental images that were related to specific aspects of the material or to desired outcomes.

With emphasis on lifelong learning, using cognitive skills is becoming more important to help people deal with new information beyond formal schooling. When cognitive

skills are taught, they are often segregated from the subject matter. Perkins and Salomon (1989) recommend research on techniques which will apply cognitive strategies to content-specific subject matter. Di Vesta and Finke (1985) recommend further investigation on elaborations as an important characterictic in instruction. Di Vesta, Ingersoll and Sunshine (1971) note the need for further investigation concerning imagery and its interactions with task and stimulus variables. Bransford et al. (1982) advocate designing elaborations that are congruent with the content material.

Since novices may have difficulty making meaningful associations with new information, there is the chance that their images will be irrelevant or idosyncratic with regard to the subject matter (Di Vesta & Finke, 1985). In addition, the use of mental imagery to form high-quality mental representations is thought to be a factor that differentiates experts from novices (Chi, Glaser & Rees, 1989). Thus, there is a need to develop a technique for inducing imagery that is precisely related to the concepts in the learning task at hand. This type of elaboration will have the most positive influence on retention (Bransford et al., 1982; Stein et al., 1982, 1984).

The use of imagery may make a difference in performance, and is it not known whether or not interactions exist between imagery and other instructional

variables. Shepard (1978) cites the need for basic research if thought processes are to be understood. Learning more about imagery as a type of elaboration will help our understanding of cognition.

Internal imaginal representations are thought to be nonverbal. The analog or perceptual component, the architecture of which is not yet understood, is generated by discrete internal codes or "internal psychophysics" (Shepard, 1978). These are among the executive processes which mediate responses to stimuli.

Such executive processes are also employed during problem solving and creative thinking at abstract conceptual levels (Pylyshyn, 1981; Horowitz, 1983; Shepard, 1978) and are thought to be necessary for the recall of the type of complex information found on the multiple-choice posttests (Dwyer, 1978). In the present study, imagery will be used as an independent variable. Active information processing is thought to promote the personal encoding of information. A technique that makes more effective use of imagery for encoding may enhance learning and problem-solving skills.

Statement of the Problem and Experimental Questions

For thousands of years, imagery mnemonics have been known to be effective (Bower, 1970; Kosslyn, 1980), but they are not well researched as an instructional variable.

Therefore, it is not known if imagery is a viable instructional variable. In addition, Paivio's dual-code theory suggests that imagery may interact with other instructional variables, specifically visual illustrations. If such an interaction exists, the combination of visual illustrations and imagery instructions may prove to be an important combination for learning. However, this has never been shown experimentally.

Imagery instructions will be used in this study as a strategy which is intended to facilitate or promote encoding of instructional material and assist in the retrieval of that material on a posttest. Thus, the instructions may cause the subjects to use an elaborative processing strategy for encoding new information that they might not normally use. In addition, Dwyer (1978) has stated the necessity of using imaginal processes to answer comprehension questions included in the posttest.

The procedure will be to compare the achievement of learners where the independent variables are instructions to form specific visual mental images and the use of related visuals. The problems to be addressed by this study can best be stated through the following questions which were formulated from the research literature:

1. Do imagery instructions improve the achievement of specific educational objectives, such as the learning of facts (terminology), part identification and comprehension?

2. Do the instructions to form images with specific structural characteristics improve the results of a constructional task (the drawing posttest)?

3. Can this strategy be induced with the type of embedded instructions used in this study?

4. Does providing related visuals interact with the imagery instructions embedded in the text?

Hypotheses

Four hypotheses, which are congruent with the experimental questions, were formulated. Stated in the null:

H_o: Instructions to form images will produce no difference in the achievement on the criterion posttests. Means of treatments TI=TVI=T=TV.

H_o: Relevant visuals with the text will not interact with imagery instructions. F(imagery) * F(visuals) < F(table).

H_o: Imagery instructions will not effect the results of a constructional task. Means of drawing test TVI=TV=TI=T.

H_o: Imagery instructions do not induce the use of imagery during learning. Accretion means TVI=TV=TI=T.

Scope

This study is an investigation into the impact of imagery instructions on learning and achievement, interactions between related visuals and mental imagery, and the actual use of the imaginal process. The study is based on the visual learning research of Dwyer and numerous researchers in the area of visual mental imagery, including Paivio, Kosslyn, Farah, and Di Vesta.

This study is not neurophysiological in nature. Investigations into specific components of the imaginal process, as outlined by Kosslyn and Farah, are beyond the scope of this study. Briggs (1981) states that certain basic intellectual skills are prerequisites for certain cognitive strategies. This study makes no attempt to derive prerequisite cognitive skills or aptitudes necessary for successfully completing the imagery tasks.

Limitations of Study

Certain factors will limit the generalizability of results. The sample for the study was drawn entirely from the student body of The Pennsylvania State University. Thus, the generalizability of results may be limited to young adult learners or to undergraduates.

One of the data collection techniques used in this study is the self report. This type of data collection is commonly used in imagery research; however, it introduces a

source of variability into the data. Also, as part of the requirements for informed consent, the subjects were informed about the posttests. This knowledge may have acted as an advanced organizer and impacted the posttest results. Finally, subjects who received the instructions to form the visual mental images were not given extensive practice in image construction; however, a practice exercise was included in the instructions given to these subjects.

Definition of Terms

The following is a list of definitions of the terminology used throughout this paper:

Accretion. The accumulation of knowledge into established structures (Norman, 1980).

Facts. In a learning hierarchy, facts comprise the prerequisite information, including knowledege of terminology, definitions, arbitrary information, and basic identification tasks which can be found directly in the instructional materials used in the treatments.

Comprehension. Response situations that require the use of inference and the application of previously learned facts or concepts to new situations. Answers to comprehension questions are not found directly in the text of the treatment material.

Imaginal process. The deliberate construction of images in the visual buffer of the working memory with information that is perceived or retrieved from long-term memory.

Mental representation. Mental symbols, propositions, or images that contain information about the world and which can be processed (Johnson-Laird, 1983).

Visual mental imagery. A form of mental representation with visual properties often containing spatial and temporal relationships which also may be used as a cognitive strategy to form associations for learning, retrieval, and problem-solving tasks involving many types of information. Visual mental images are the result of perception or imagination.

Chapter Two

REVIEW OF THE LITERATURE

The following databases provided the main sources of information to support this study: ERIC, PSYCHLIT, and Dissertation Abstracts International. The computerized catalog system of the Pattee Library of The Pennsylvania State University provided access to the information.

The body of this chapter summarizes current research and is organized into eight sections by the following topics: imagery theory, imagery ability, imagery and cognition, imagery and associative learning, facilitating imagery, learning strategies, visual illustrations, and processing text-based information.

Current Imagery Theories

Paivio (1969, 1972, 1975) is well known for his dual-coding theory where verbal and nonverbal information are processed in functionally independent, but interconnected, systems. The visual imagery system is specialized for perceptual knowledge: encoding, storing, organizing, transforming, and retrieving spatial information about concrete objects and events. The other system deals with information in discrete linguistic units and is specialized to deal with sequential information. Dual coding is most

likely to occur familiar or easily named pictures are present. The distinct verbal and visual codes interact extensively for learning.

Kosslyn (1980) writes that images are similar to data structures which can be processed in many ways. He agrees with Bower's (Kosslyn, 1980) viewpoint that semantic memory contains a common code or a "common generative grammar" (p. 133) which may underlie both verbal and nonverbal processes. Kosslyn also draws an analogy between information-bearing structures of computers and the information-storing and processing portions of the brain. Images are characterized as transitory data structures in an analog spatial medium. He notes that although the theory and the model of mental imagery are incomplete, a good deal is known about a type of array called the visual buffer which is euclidean in shape and two dimensional. The brain cells that comprise this array have positions that correspond to the visual field. Within the buffer, that pattern of activation is isomorphic to the object's visible space. The buffer may also contain other information from the memory or visual system. For image generation, much information about properties required to reconstruct an object comes from long-term memory. During the image-generating process, the visual buffer can fill with information from more than one long-term memory file,

placing various objects in different orientations in the buffer.

Imagery Ability

Precisely why some use imagery more than others is unknown. Imagery and other individual difference variables are highly complex (Di Vesta, 1973). It is a valid assumption that some people learn by forming images, while others learn by using verbal encoding. Also, the answers may be rooted in cultural and environmental factors including the quality and quantity of the perceptual stimulation provided, language acquisition, and the use of images in preverbal life as a substitute for the mother's presence (Horowitz, 1983).

There seem to be several reasons why imagery would emerge as the preferred mode of operation. A certain amount of the capability to form images is determined neurophysiologically. Also, the imaginal process may have special attributes for processing certain types of information or as a strategy which complements various cognitive styles.

Humans are capable of forming mental images long before they can think in lexical form. Through cognitive growth, organizational capacities developed for the imagery mode of representation advance to a higher organizational level due to the existence of additional schemata. Since

imagery exists as a method of dealing with information prior to the existence of lexical thought in early childhood, the image-based schemata and strategies are used at first to deal with words (Horowitz, 1983).

Di Vesta et al. (1971) note that imagery in adults is variable and probably a strategy preference, while it is more heavily utilized as a skill in children. Thus, as communication skills become more advanced, the ability is gained to sequence and organize words by meaning rather than image attributes alone. Horowitz (1983) feels that such organizational abilities are also used for forming sequences of visual images as a method of dealing with and processing information. Shepard (1978) feels that imagery is important for high-level thinking skills where concrete representations merge with related associative processes at abstract conceptual levels. In problem solving, experts solve problems by forming sophisticated mental representations of problem components (Chi, Glaser & Rees, 1981; Gilhooly, 1989).

Horowitz (1983) concludes that the schemata involved in the formation of images and those derived as a result of language development are both used in many performance tasks. As image formation aids in the representation and organization of lexical information, the schemata for lexical information enhances the interpretation and storage of information coded as images. Therefore, the ability to

process information is related to both image representation aids and lexical organizational abilities. The two modes interrelate under normal circumstances, blending together without a clear division. Mental images take routes that are usually automatic; they are transformed into words, or another form of representation, and the sensory vividness is reduced (Horowitz, 1983). After transformation, the image is labeled and stored for later retrieval.

Imagery and Cognition

Summarized by Paivio (1972), the ancient Greeks knew that bizarre images were effective mnemonic devices and in 1929 Kohler reported that the imageability of noun pairs made them easier to learn than nonsense syllables. Tasks that require meaningful processing facilitate learning. Imagery is an elaboration strategy that can give learners a more meaningful representation of the relationships in the material to be learned (Kulhavy & Swenson, 1975; Weinstein & Mayer, 1986; Anderson & Kulhavy, 1972).

Miller (1956) believes that the process he calls recoding can be studied by specifying the method, for example, instructions to form mental images. Since it promotes information processing, the use of imagery has been demonstrated to be an important factor in learning and retention (Mayer, 1982). As a form of elaboration, it helps form associations (Weinstein & Mayer, 1986). Tversky

(1973) suggests that information is coded in a manner depending upon the anticipated usage or application. Edelstein (1981) reported that elaboration strategies, in particular visually oriented mnemonics, facilitated information integration and subsequent higher-order learning of abstract concepts.

According to Beritashvili (1969), learning accomplished with mental imagery requires only a single trial for long-term retention. Bizarre images are found to increase distinctiveness (O'Brien & Wolford, 1978) and therefore enhance learning. However, Hanawalt (1954) found that bizarre images are not superior to common images. Reese (1977) found that compound images are superior to simple images.

Shepard and Podgarny (1978) report that giving explicit instructions to subjects helps ensure internalization of information which will lead to better test performance. Although there was no significant difference in achievement test scores in a study conducted by Anderson and Kulhavy (1972), the subjects who reported that they used imagery whether or not they received imagery instructions learned more than those who did not. Conversely, investigations of imagery effects on learning and recall tasks have failed to show that the imagery instructions themselves are responsible for improved task performance (Kosslyn, 1980).

Concrete quality of stimulus material can aid memory and retrieval of information. Concrete nouns evoke high levels of imagery and are more easily recalled than those of low concreteness (Paivio, 1976). Paivio suggests that images function as a conceptual peg for storage and retrieval of information (1979, 1975).

Image Generation. The same cognitive processes are used during image generation and perception; however, the stimulus is absent during imagery (Neisser, 1972). Visual mental images are constructed in the visual component of the working memory piece by piece in a manner consistent with the meaning ascribed to it (Kosslyn, 1980; Roth & Kosslyn, 1988). When constructing mental images, the third dimension of a pattern or figure appears in a near-to-far sequence. Thus, three-dimensional images are not generated all at once as a whole, but are constructed piece by piece with the parts thought to be nearest generated first according to a person's understanding. As each part is added to the image, additional time is required for the image construction. Thus, subjects given directions to construct a complex image will require more time than a subject required to image a simple object. Also, a distant probe requires more time to evaluate than a nearer one.

Also, as new information is encountered and processed, existing information can be reinterpreted causing existing images to be relabeled or replaced in

semantic memory. Thus, the conceptual interpretation of images changes as they are processed in light of new information. Such a task occurred in a Finke et al. (1989) series of experiments in which the subjects imaged and interpreted a collection of parts given in a verbal description and formed an image of an exemplar from a conceptual category.

Uses of Mental Images. The mental imagery processes seem to interact primarily with higher-level visual routines (Ullman, 1984). Images are conceptual interpretations of symbols and patterns that are important parts of mental representations (Finke et al., 1989) and provide a basis for reconstructing more accurate memories (Richardson, 1972). Imagery is part of the qualitative process important to creative ability and mathematical insight (Gagne, 1985; Pinker, 1984). Imagery has long been used as a strategy to represent conceptual problems in architecture, mathematics and other mental synthesis tasks that require mental representations of spatial relationships (Antonietti et al., 1985). Possibly the use of imagery is a factor that enables experts to form higher quality mental representations during problem solving than novices (Chi, Glaser & Rees, 1981).

Many scientists and inventors claim that imagery has an important role in their creative process (Shepard, 1978). Classical electromagnetic theory was formulated by

James Maxwell who reportedly formed a mental image of each problem. In addition, Einstein stated that he rarely thought in words. Certain branches of chemistry and molecular biology rely heavily on spatial relationships in their work. In the discovery of the structure of the DNA molecule, Watson and Crick can recall how the work was aided by their ability to image (Shepard, 1978).

Imagery has also gained widespread use in clinical situations as a method to control autonomic and affective states in stress reduction, deconditioning of phobias, and mental practice of motor skills for athletic training (Burhans et al., 1988; Richardson, 1972).

Researchers have little or no information regarding the amount of knowledge average people have regarding the use of imagery. An investigation by Denis and Carfantan (1985), which queried adult subjects, revealed that most people are aware of imagery as a useful thought process. Subjects who were surveyed felt that imagery would be a superior strategy for remembering pictures over words and that imagery instructions would positively effect verbal learning. Thus, many people believe that imagery represents an efficient strategy for most cognitive processes, but the exact role of the imaginal process and the number of imagery phenomena that exist are largely unknown to researchers.

There is general agreement that images are manipulated and transformed by the working memory for tasks requiring spatial, size judgments, or visual information (Kosslyn, 1980, 1984). Images serve to reduce the information processing burden by implicitly representing spatial information in a way that allows the greatest amount of information to be held in working memory at one time (Gagne, 1985). The dual-trace theory of Bower (Bower & Hilgard, 1981) recognizes imagery as a technique to maximize learning in minimal time. Thus, images are valuable accommodations to the limited capacity of the working memory.

Function of Imagery. Imagery can function literally, where the subjects memorize a stimulus pattern, or subjects can encode the stimulus and obtain further information from an image (Marks, 1972). Thus, images are generally the result of highly processed information which should, in turn, influence information processing (Kosslyn, 1980).

A primary function of imagery is to process geometric spatial information and see either new or previously available patterns using mental symbolic representations (Finke et al., 1989). Mental images can combine with perceptions for problem solving. This may occur in such a way that emergent spatial relations can be determined from an image percept-hybrid (Farah, 1989).

Image generation can also change the characteristics of a visual field, thus affecting visual processing. Imagery can function as either interference for perception or as a facilitator of perception (Farah, 1989b). When a visual stimulus is specific to or related to the image, imagery facilitates perception. However, imagery can impede certain stimulus detection tasks (Farah, 1989a). Therefore, the mental imagery process can affect the processing of visual stimuli. Mental representations can also be shared at various levels by imagery and perception.

Farah (1989b) has found that a stimulus is more likely to be detected if it lies within the space or field occupied by a projected mental image. The mechanism by which imagery alters perception is not well understood. Imagery is thought to be similar to visual attention, making it easier to detect stimuli in the visual field due to changes in local criteria for stimulus detection.

The three-dimensional quality of images is important and is discussed by Roth and Kosslyn (1988). One purpose of imagery may be to simulate real-life scenarios that are difficult to consider in other ways. Distance information is important for navigating in the environment, and the most information is generally known about the nearest points. Images are generated in a near-to-far sequence because this is the way the environment is normally experienced: by first localizing near surfaces and then the

more distant surfaces. Since this is thought to be a top-down process, it is also thought to involve less chance for error than other possible sequences that help us process information to navigate in the world.

It is known that visual and verbal information are stored in different parts of the brain (Travers, 1982). It is not known exactly how images are preserved in long-term memory. One theory developed by Anderson and Bower (1973) states that information is stored either as propositions or in a common verbal format. Paivio's (1971, 1972, 1979) dual-code theory holds that information is encoded and stored in two formats: verbal and imaginal. Support for this theory comes from research demonstrating that imageable (concrete) information is recalled better than abstract information. Thus, memory is superior for imaged information since it is thought to have two representations in long-term memory.

Some image theorists contend that a mental image is a direct copy of a visual display (Olson & Bialystock, 1983). This view seems to assume that the visual information is stored in an uninterpreted form prior to being integrated. However, in recent years, most concur that mental images result from the perception and interpretation of objects or information. Thus, lexical information can also be encoded as an image and stored in memory. The fact that letters and words are recognized to a large extent by their shape

and appearance indicates that they are stored as images (Posner, 1973).

Pylyshyn (1981) explains that the ability to form mental images relates to prior knowledge, which is a limiting factor both in the formation of images and the subsequent manipulation of images, not to other fixed properties of the information. Kosslyn (1981) explains that mental images are used to store information, functioning as a type of visual buffer. Information is preserved in the visual buffer and operations such as scan, focus, zoom, and rotate can be performed on an object's primary characteristics. The visual buffer contains images which are recalled and constructed from long-term memory, as well as those derived from the actual viewing of an object (Kosslyn et al., 1984). Images are not always present in the working memory. They are constructed using input from separately stored information which is retrieved from long-term memory.

Imagery and Working Memory. Due to the information gathered from studies of imagery, the general model of the working memory, which characterizes the working memory as an undifferentiated short-term store, is no longer held valid. Hitch et al. (1989) mention that the working memory has several subsystems or components to deal with different types of information: a visual-spatial component, a verbal

or phonological component, an active component, and a passive component.

These subsystems of the working memory deal with different types of information through different processes. Visual information automatically enters the visual-spatial store, but the labels are held in the verbal (phonological) store. Hitch's research supports the dual-code model of working memory. With maturation, the verbal code complements rather than replaces visual coding.

The visual component holds spatial and temporal information, such as size, shape, orientation, and recency, and undergoes little change with maturation. The passive component is of interest since unattended visuals gain automatic access to the part of the visual working memory that is involved with active visualization. Hitch notes recent work where exposure to unattended visuals disrupts imagery mnemonics. Mental images held in the visual-spatial component of the working memory are the result of an active process which is very similar to an attentional state (Farah, 1989). Hitch calls for further research to better differentiate passive and active components of working memory.

Imagery and Associative Learning

Sensory images are most likely to result when the stimulus material is of a concrete nature (Paivio, 1969; Di

Vesta, 1973; Gagne, 1985). They are symbolic processes "linked developmentally to associative experiences involving concrete objects"...(Paivio, 1969, p. 243). Also, Di Vesta et al. (1971) and Gagne (1985) suggest that the degree of task concreteness interacts with the use of imagery. The process of image formation is psychologically complex and involves symbolic transformation and coding stages.

Verbal information is transformed from words into concrete images and back into words. Here, the "picturability" of nouns contributes to the mediation process: "The higher the concreteness of stimulus items, the more likely they are to evoke sensory images that can function as mediators of associative learning and memory" (Paivio, 1969, p. 243). However, the mnemonic effectiveness of imagery is primarily due to the spatial properties rather than pictorial qualities (Neisser, 1972). Paivio (1972) also notes that in associative learning, imagery is more effective than a verbal mediator and is less susceptible to interference than verbal processes; these are conditioned sensations where appropriate words act as conditioned stimuli or as constructs that the learner actively generates.

Experimentation with paired-associate learning has found that as a mediation strategy in the formation of associations imagery is often preferred and that high-rated

image-evoking words are learned more effectively than words high in meaningfulness (Paivio, 1969; Bower & Winzenz, 1970). Di Vesta and Ross (1971) note that in paired-associate learning, the use of imagery seems to be an efficient strategy for transforming a stimulus into usable form. Imagery use may be an organizational strategy for structuring inputs into units having dominant spatial properties (Di Vesta & Ross, 1978).

Facilitating Imagery

The nonverbal code is aroused directly by pictures but is aroused indirectly by concrete words (Paivio, 1972). The summation of availability of both codes is the highest for familiar pictures, since the use of names is involved in the encoding process.

Regulatory processes for images, such as inhibitory and facilitative mechanisms, are discussed in psychoanalytic literature and summarized by Horowitz (1983). Normally, images are uncontrolled, contents are unregulated and the only awareness occurs when images are unusually vivid.

Since the ease and tendency to image often relies upon an anticipation of application or prior conditioning (Pylyshyn, 1981; Tversky, 1973), it is difficult to identify or isolate which processing mechanism is being used. Pinker (1984) states that "if imagery is nothing but

the use of tacit knowledge to simulate physical events, then the only constraints on what we can do in our images should stem from what we know can or cannot occur in the world" (p. 44). Hence, it is not feasible to ask people to image unfamiliar things.

Imagery is the result of both imagination and perception (Johnson-Laird, 1983). Hence what we image is often limited to what has been perceived. Image formation interacts with various types of materials (Lindauer, 1972) and, thus, is influenced by various forms of input. However, the exact input-output routines are not generally known (Pinker, 1984). Especially important to the image-forming system is perceptual information. Image formation is influenced by both internal and external processes (Farah, 1989). For example, perception influences the production of images and resulting mental images may also influence future perceptions.

Regulatory influences, such as those which control selective attention, would be those that amplify stimuli or control the rate of information transmission (Horowitz, 1983). Executive processes, such as problem-solving strategies, may operate at various levels, influenced by both neurobiology and psychologic factors.

Psychotherapists use imaging techniques, instructing patients to form images. Breuer and Freud (1955) directed patients to form visual images in order to facilitate the

recall of information. Jung (1955) developed a technique called active imagination where conscious, organized thought is set aside and unconscious thought emerges in the form of images which are then analyzed by the conscious mind. In these cases, the overall external stimulus that facilitates the formation of visual images is the suggestion or instruction to form images.

Many other researchers have instructed subjects to form images. With instructional materials, Anderson and Kulhavy (1972) gave imagery instructions to high school students and found that they did not recall factual information better than the control group. An explanation of this result was that older learners no longer rely on imagery for learning factual information, but have replaced it with other information-handling strategies. Anderson and Hidde (1971) experimented to determine if imagery facilitated sentence learning for undergraduates. Those who were instructed to form images recalled more than three times as many words on a surprise test as the control group. Experimentation on fifth- and sixth-grade students by Kulhavy and Swenson (1975) showed superiority for the use of imagery with younger students. Carrier et al. (1983) used sixth-grade students in a experiment that also included field dependency as an independent variable. Although the results were not significant, the field-

independent subjects who received the imagery instructions scored higher than their field-dependent counterparts.

Learning Strategies

Learners are known to use various techniques during learning. Cognitive strategies are behaviors and thought processes that influence the encoding and integration of new information (Gagne, 1985; Weinstein & Mayer, 1986). Thus the learning of new information is partially dependent on strategies developed and used by the learner for information processing (Anderson, 1970; Mayer, 1970). Weinstein and Mayer (1986) define three classes of learning strategies for both basic and complex learning tasks: rehearsal, elaboration, and organizational. Imaginal processes are important parts of both elaboration and organizational strategies. Rehearsal tasks involve selection and acquisition, and on the complex level, selective perception. Basic elaboration strategies involve integration or forming mental images to form internal associations, while complex elaborations involve the construction of new relationships. Organizational strategies can involve selection and the construction of new relationships among information in working memory and complex organizational strategies involve forming external connections between incoming information and prior knowledge.

On an information-processing continuum, cognitive strategies are a means of bringing about more meaningful processing. Elaboration and organizational strategies involve the learner in active voluntary processing during the leaning task (Mayer, 1982). They are an important way of forming relationships that link prior knowledge to new information thus reducing the arbitrariness of the new material.

Elaboration includes the processes of construction and integration. With these processes, the learner is actively building internal connections in working memory and external connections by relating these to prior knowledge (Stein et al., 1984; Bransford et al., 1982). Since elaborations, such as forming mental images, leave a more distinctive trace in memory, they also help the assimilation and retention of new information.

Visual Illustrations in Text

The purpose of instructional design is to regulate attention and facilitate information processing by manipulating instructional variables (Anderson, 1970). The use of visual illustrations with instructional text has proven to be an important instructional variable. Dwyer et al. (1988) have conducted extensive research on the characteristics of effective visual illustrations (visuals) in text. Visuals help learners isolate and identify

important material, recall prior knowledge, provide interaction with content, and enhance information acquisition. Winn (1989) also summarizes the advantages of visuals, noting that they make the abstract more concrete.

The human sensory system processes and draws inferences from visual stimuli (Larkin and Simon, 1987). Further, visuals efficiently and effectively group information and support perceptual inferences, a process which is largely under control of the learner who has beliefs about which information is most important and therefore will receive the most attention (Winn, 1989).

Processing Text-Based Information

Certain information seems to be encoded best when simultaneously organized, which is typical of images, in contrast to the sequential organization of verbal information (Horowitz, 1983). Results of a study by Long (1986) indicated that a complex relationship exists between mental imagery and reading comprehension. Both verbal and imaginal systems are involved in reading; however, imagery is hypothesized to be pervasive during reading. In Long's study, the subject's report of imagery use was highly correlated to an index of text interest. In another study, imagery instructions improved the literal reading comprehension of both abstract and concrete text passages

for ninth grade difference-poor readers (Dillingofski, 1980).

Investigations into the process relating to the retention of verbal information find that when words are connected meaningfully, surrogate structures are generated that are not entirely dependent upon the semantic content of the words themselves (Pompi & Lachman, 1967). This surrogate system is a type of recoding process that reflects the important concepts and contains several dimensions and combinations of words, visual images, summary ideas, and themes. Therefore, imagery may be an important, but yet to be understood, part of the process known as encoding or chunking. The form that encoding takes is thought to be the lifeblood of cognitive processes (Miller, 1956). However, the imaginal component of these processes can be difficult to access and study.

Chapter Three

METHOD

The research design is a completely crossed, completely randomized two by two posttest-only control group design. According to Campbell and Stanley (1966), this is one of the true experimental designs. The two by two design is used to analyze the effect of two independent variables simultaneously and to determine whether or not the two independent variables interact.

The independent variables used in the treatments are the visual illustrations (visuals) and instructions to form visual mental images while reading. For each of the four cells, the following dependent measures (within-group variables) were obtained: factual learning, identification of parts and structures, comprehension, and total criterion (a combination of the three previous tests); drawing; and measures of time of accretion and time of testing.

The treatments consisted of four versions of a text-based 2000-word module on the parts and function of the human heart. This module had available three criterion-referenced multiple choice posttests which have been validated for specific types of learning (Dwyer, 1978).

Sample

The sample for the study was drawn from student volunteers recruited for this specific purpose. Subjects were recruited from an Ed Psych 14 class at Penn State. To ensure that the subjects were novices in the content area of the study, the students were screened for prior knowledge of the heart function, i.e. pre-med or physiology majors were asked to participate in other graduate research. An arrangement was made to compensate all participants with course credit.

Procedure

Classrooms were scheduled for small group testing sessions. Subjects were randomly assigned to groups and the data were recorded in such a manner as to ensure confidentiality. Each subject received a packet of material upon entering the room. The packet contained the informed consent form, an explanation of the study, a text-based treatment booklet, a time-recording sheet, a post-treatment questionnaire, and the posttests and answer sheet.

The subjects were given an orientation to the procedures and the chance to ask any questions of the investigator. The investigator was present at all sessions. Names were not recorded on the test instruments or answer sheets. Prior to reviewing the instructions, all

participants signed an informed consent form (Appendix A) and were allowed to withdraw at any time. The investigator checked all packets before the subjects left the room.

Independent Variables

The treatments consisted of the instructional text about the human heart, with related visual illustrations and instructions to form visual mental images varying between the groups.

Visual Illustrations. The treatment booklets and related visuals were based on those used previously by Lamberski (1980). The visual illustrations were clear, unambiguous line drawings containing verbal labels on the structures.

Imagery Instructions. Based on Kulhavy and Swenson (1975), imagery instructions were placed on each page of the treatment booklets for the instructed groups. In order to correctly derive the instructions to form visual mental images, the method described by Dwyer (1978) for the placement of visuals in text was followed. The treatment without visuals (control) was given to 19 subjects as a pilot study (Appendix C). An item analysis (Gronlund, 1985) of their posttest results formed a guideline for the design of specific instructions to form images. Items with an item difficulty index of less than 60 percent were included in the formation of the instructions. The

appropriate imagery instructions were then inserted on each page of the booklets for the imagery treatments. Shepard and Podgarny (1978) and Bransford et al. (1982) state that specific instructions help ensure better internalization and, thus, better posttest results. Also, placing the instructions on each page was rooted in the need to maintain the strategy throughout the treatment. Such a technique was used with general imagery instructions by Kulhavy and Swenson (1975). The text material that related to the specific questions was then identified for each question. For example, the instructional material that relates to questions 9, 13, 30, 31, and 32 are found on page 3 of the text used for treatments 3 and 4. Thus, the instructions inserted on page three of the third and fourth treatments will relate to these questions. However, 86 percent of the subjects answered questions 9 and 32 correctly. For questions 13, 30, and 31, only 57 percent of the subjects answered questions 13 and 30 correctly, and only 43 percent answered question 31 correctly. Therefore, the imagery instruction was formulated which was relevant only to questions 13, 30, and 31. Question 13 was an identification item where the subjects have to identify the myocardium. Questions 30 and 31 are terminology items that deal with the definition and function of the myocardium. Thus, the imagery instruction reads: "Picture in your mind

the heart's muscle--the myocardium--relaxing and contracting."

In another example, the text that relates to questions 17, 25, 40, and 41 was found on page 10 of the imagery treatments. Eighty-six percent responded correctly to comprehension test item 41. Only 29 percent of the subjects answered item 17 correctly, an identification item about the aortic valve. Fifty percent of the subjects answered question 25 correctly, a terminology question about the fact that the left ventricle is the strongest part of the heart. Thus, the imagery instructions for page ten of treatments three and four reads: "Picture in your mind the oxygenated blood from the strong left ventricle passing through the aortic valve."

Treatments

The experimental materials used as the treatments are included in Appendix D.

One treatment, the text only (T), consisted of a booklet containing the instructional script with neither visuals nor instructions to form images. The second treatment, text plus instructions to form visual mental images (TI), should be superior to treatment T, since the embedded visuals, theorized to interfere with personal encoding such as the formation of mental images (O'Brien and Wolford, 1982) will be absent.

The third treatment, text with related visuals and no imagery instructions, should be superior to treatment T due to the principle of cue summation where the effect of the cues supplied by the visuals makes learning more complete (Severin, 1967), and the research of Dwyer (1978) which has found that learning is enhanced when specifically designed visuals are used with the text.

The text plus visuals plus instructions to image, the fourth treatment, should be superior to all other treatments due to the summation of the visual images and the imaginal processes facilitating an increased amount of selective attention and the formation of concrete mental representations of the spatial, temporal information in the treatments, and therefore learning and achievement.

Dependent Variables

The three criterion-referenced multiple-choice posttests each containing 20 questions are terminology, identification, and comprehension (see Appendix E for the complete tests).

The terminology test measures knowledge of basic facts and definitions as presented in the text. The following is a sample terminology question:

30. The _____ is another name for the part of the heart called the heart muscle.

a. apex d. myocardium

b. epicardium e. septum

c. endocardium

The identification test is a recognition test that provides visual cues (a heart diagram with numbered arrows) for naming and discriminating heart structures. An example of an identification test question follows:

1. Arrow number one (1) points to the

a. septum d. pulmonary vein

b. aorta e. none of these

c. pulmonary artery

The comprehension test measures the subject's understanding of the heart's function and requires the subjects to generate concrete visual images in order to locate and position "parts of the heart in their mind's eye" and "mentally simulate functions and movements of the various parts of the heart"...(Dwyer, 1978, pp. 46-47) as this information is retrieved. The following is a sample comprehension question:

57. During the second contraction of the systolic phase, in what position is the aortic valve?

a. fully open c. partially closed

b. partially open d. fully closed

Last, a 20-item drawing test is a constructional task which was used to evaluate the subject's ability to reproduce a heart diagram. The test involves drawing the

human heart and its structures given a numbered list of twenty structures. One point is given on the test for each correctly placed structure. Farah (1984) identified six tasks that are relevant to assessing imagery ability. One of these tasks, a constructional task (drawing), is related to the generation of mental images. Such a task requires learners to generate an image in the visual buffer before they can correctly reproduce the anatomical structures and symbols with respect to each other and concrete referents. This is the visual-to-motor translation process described by Farah (1984) in her extension of Kosslyn's (1980) imagery model. Also, Paivio (1969) states that imagery is specialized for spatial representations. Thus, those who received instructions to image should be favored in this task.

The following average reliability coefficients for each criterion test have been reported by Dwyer (1978): 0.83, terminology; 0.81, identification; 0.77 comprehension, 0.83 drawing, and 0.92 total criterion (P. 47).

A measure of time was also recorded to the nearest second by the subjects for both accretion (the reading portion of the treatments) and the testing portion.

Theoretically, those receiving the imagery instructions should take more time to complete the reading task if imagery was induced during accretion (Kosslyn et

al., 1984). If imagery was used extensively during the testing portions, the subjects should also require more time.

A post-treatment questionnaire (Appendix B) was also used to assess the subjects' perceptions of their use of imagery in the experimental situation. This questionnaire used a Likert scale and comprised four items which addressed the subjects' use of imagery. The first item, for example, asked the subjects if they "formed pictures in their mind" during the task they had just completed. The remainder of the questions collected a profile of the subjects' imagery, or mental "picture," use during formal learning, other situations, and asked the subjects to rate the accuracy of their images. A fifth item was a multiple-choice item which inquired about the subjects' dominant learning strategy during the treatment.

Research Evaluation

Originally, each cell had 40 subjects. To determine if equal proportions of males and females existed in each cell, the number of males was totaled in each group. Group TVI had 15 males, while the group T had only 3. The superiority demonstrated by males in spatial visualization tasks, which is summarized by McGee (1979, 1982), could have biased the results. Thus, to deal with the potential sampling bias, the cells were then balanced with equal

proportions of males and females by randomly omitting answer sheets. The result of this was 3 males and 15 females in each group for a total of 28 subjects per cell. The omitted tests were not scored.

Tests were machine scored using Tessia software. The imagery use questionnaire was scored using the Likert software. Hypotheses were tested using ANOVA statistical tests with SYSTAT software. ANOVA tests were chosen because they are statistically robust tests for the analysis of the effects of factors, as well as interactions between factors, in a factorial design.

To report trends in imagery use as indicated on the questionnaire, Pearson product moments were calculated for these data.

Chapter Four

RESULTS

This chapter presents the results of the statistical analysis for hypothesis testing, as well as a discussion of the results. The first calculations to be performed on these data were the descriptive statistics. The summary of these data is presented in Appendix G. The reliability coefficients of the posttests and the questionnaire are presented in Appendix F. ANOVA tests were then used on all dependent measures. The relevant ANOVA summary tables are included in this chapter. An alpha of 0.05 was used for all statistical tests.

Results of the ANOVA Tests

Analysis of the dependent variables revealed main effects of the independent variables in many of the tests (table 1). No interactions were observed between the independent variables; thus, no multiple-comparison follow-up tests were required.

Hypothesis Testing

The results of the ANOVA tests were used to test the four hypotheses presented in Chapter One. Using an alpha of 0.05, the critical value of F for 1 and 108 degrees of freedom is 3.92.

Table 1

ANOVA Summary of Dependent Measures:

Total Criterion, Drawing and

Accretion Time

Total Criterion (Results of three multiple-choice posttests)

Source	df	MS	F-ratio	p
Imagery	1	22.32	0.2	0.66
Visuals	1	594.32	5.32	0.02*
Imagery* Visuals	1	228.57	2.04	0.16
Error	108	111.79		

Drawing

Source	df	MS	F-Ratio	p
Imagery	1	75.57	4.79	0.03*
Visuals	1	594.32	37.71	0.00**
Imagery* Visuals	1	0.32	0.02	0.89
Error	108	15.76		

Accretion

Source	df	MS	F-Ratio	p
Imagery	1	1020322.32	15.79	0.00**
Visuals	1	410190.04	6.35	0.01*
Imagery* Visuals	1	9362.27	0.15	0.7
Error	108	64582.23		

* $p < 0.05$

** $p < 0.001$

First hypothesis: H_o: Instructions to form images will produce no difference in achievement on the criterion posttests. Rejection rule: F(imagery) > F(table). The analysis of the total criterion test scores yielded a significant main effect for the visual illustrations factor: F(visuals) = 5.316 and F(table) = 3.92. The first hypothesis is retained since the imagery factor did not have a significant effect.

Second hypothesis: H_o: Relevant visuals with text will not interact with imagery instructions. Rejection rule: F(imagery*visuals) > F(table). There was no significant interaction effect seen as a result of the analysis. The second hypothesis is retained.

Third hypothesis: H_o: Imagery instructions will not effect the results of a constructional task. Rejection rule: F(imagery) > F(table). Both the visual illustrations and the imagery instructions factors produced significant main effects on the drawing test. The null hypothesis is rejected since the imagery factor produced a significant main effect (F = 4.795). The drawing test mean of group TI (11.29) was significantly higher than the group T mean (9.75). The drawing task required the subjects to generate an image in the visual buffer, inspect and describe that image, and then copy the inspected contents of the visual buffer onto paper (Farah, 1984).

Fourth hypothesis: H_o: Imagery instructions do not induce the use of imagery during learning. Rejection rule:

F(imagery) > F(table). The ANOVA of accretion time means revealed significant main effects for both factors: F(imagery) = 15.799 and F(visuals) = 6.351.

Kosslyn (1984) states the increased time is the hallmark of imagery. Also, Kosslyn et al. (1983) summarize several research reports where more time was required to image complex scenes described in detail in a text passage. As stated in Chapter Three, the higher accretion time mean of group TI (834.43 seconds) versus the group T mean (625.25 seconds) is an indication of imagery induction. Thus, the induction of imagery with imagery instructions is considered tenable. The imagery factor also produced a stronger main effect than the visual illustration factor. Therefore, the null hypothesis stating that the use of imagery cannot be induced with imagery instructions is rejected.

Post-Treatment Questionnaire Data

Univariate ANOVA tests were also run on the separate Likert items and the total Likert scores of the questionnaire responses. No significant differences were found between groups on the questionnaire items as a result of the ANOVA tests.

Three of the questionnaire items (Likert items 2-4) inquired about the subjects general use of imagery. A split-plot ANOVA was done with BMDP statistical software using these three items as three levels of a within-group

"imagery use" factor. No significant differences were found on the analysis, which indicated that the subjects comprising the sample were similar in overall imagery use.

In addition, to analyze the question that inquired about the dominant strategy, a chi-square test for homogeneity was done to determine whether a significant difference exists among the responses of the four groups. Since the expected frequency in more than 25 percent of the cells was less than five, the last two columns were collapsed into one "verbal" category. This resulted in three categories rather than the original four (cf. the categories of the Paivio, Smythe and Yuille study referenced in Paivio, 1969). The chi-square value (10.72) was not significant. The critical value of chi square with 6 degrees of freedom is 12.59.

Further Discussion of Criterion Posttests

ANOVA tests were done on the identification, terminology, and the comprehension posttest scores in addition to those required for hypothesis testing. Of the three criterion posttests, the visual factor produced main effects (TV mean = 13.79, T mean = 12.54) for only the identification test (Table 2), F(visuals) = 12.05, p=0.001. The identification test is a type of visual test, since a diagram is used to identify parts when answering questions.

Group TVI had the highest mean on the identification test (14.43), while the TI group's mean was the lowest

Table 2

ANOVA Results:

Identification Test

Source	df	MS	F-Ratio	p
Imagery	1	11.57	0.78	0.38
Visuals	1	180.36	12.05	0.001**
Imagery* Visuals	1	46.28	3.099	0.08
Error	108	14.94		

** $p < 0.001$

(10.61), a pattern that was seen throughout the multiple-choice test scores. The fact that the TI group had the lowest mean on each of the three parts of the criterion posttests allows the conclusion that visually presented information is important to novices. When used correctly, visual displays summarize important information (Winn, 1989) and activate both the verbal and visual codes (Paivio, 1966, 1972). In the absence of a concrete visual referent, novices may form images that are idiosyncratic and meaningless, which can interfere with learning (Runquist and Hutt, 1961).

Interaction Between Independent Variables

Although the values for an interaction effect are not significant, the identification test value (p=0.081) suggests either a moderate interaction or that these factors have the potential to interact. The dual-code theory supports the existence of an interaction and the posttest means of the TVI group were consistently the highest in this study. Imagery is specialized for spatial information and the identification test required subjects to recognize structures in their spatial orientation on a line drawing. In future research, there is a good chance of finding that visuals and mental imagery are an important combination for learning, particularly when the treatment and dependent measures emphasize spatial information.

Questionnaire Results

The four Likert items and a multiple-choice item that inquired about the use of a dominant learning strategy were the basis for self-reports of the subjects' perceptions of imagery use. As previously stated, the ANOVA tests of the survey items showed no significant differences on these measures. Figure 3 shows frequency histograms for the Likert items. The task use of imagery (Likert 1) appears to be homogeneous. A similar pattern emerges for the other Likert items which are more demographic in nature and concern imagery use in both formal learning (Likert 2) and other situations (Likert 3), and image accuracy (Likert 4).

Imagery as a Dominant Strategy

The fifth questionnaire item had subjects indicate which strategy was their dominant learning strategy during the treatment. Four choices were given, one of them was imagery while the other three were verbal strategies. The proportion of imagery use as a dominant strategy was plotted by group (Figure 4). On the same graph, the proportion of those in each group who claimed to have used imagery heavily in the task was also plotted for comparison. Apparently, heavy imagery use does not always indicate that imagery is also the dominant learning strategy. Thus, when imagery is used, it is not always used exclusively. This is plausible since imagery is thought to be an attentional state related to perception

(Farah, 1989b) and the brain is a parallel processor for tasks involving attention and perception (Johnson-Laird, 1983; Gilhooly, 1989).

The lowest proportion of imagery use as a dominant strategy was by the TI group (0.14), which means that verbal strategies were dominant for a majority of the subjects in this group. Novices trying to learn relatively technical information without the visual referent may have had to rely on strategies other than focused imagery. The images they could construct in response to the instructions were probably too idiosyncratic to facilitate learning and multiple-choice posttest achievement. In group T, equal proportions of subjects used verbal imagery strategies. For group TVI, 0.39 used imagery as a dominant strategy, while the proportion in group TV was 0.34.

Patterns of Imagery Use

Pearson product moments were then calculated on the data (Table 3). For this sample size, the critical value at the 0.05 level of significance is 0.195. Several trends in imagery use can be reported.

The subjects who reportedly spent more time reading (accretion) performed better on the drawing test (r=0.267). The increased reading (accretion) time is being attributed to the use of imagery. Those who used imagery more heavily had processed and stored more information in long-term

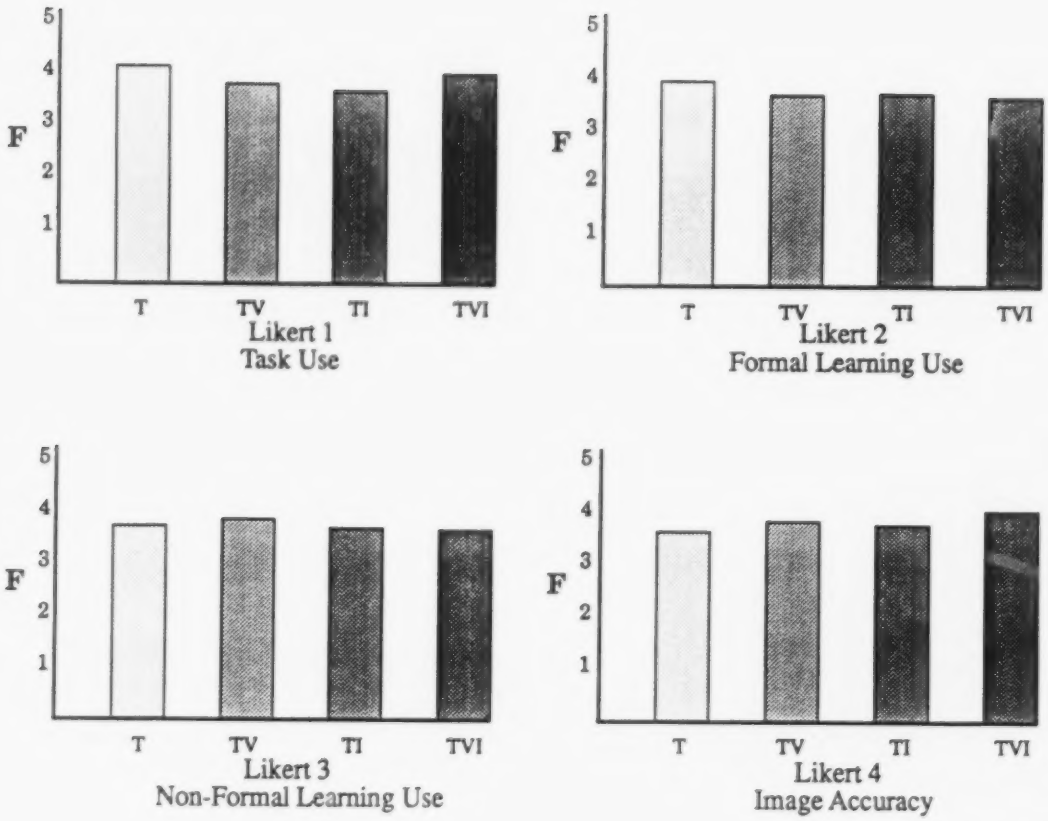


Figure 1. Frequency of Responses to Likert Items x Group.

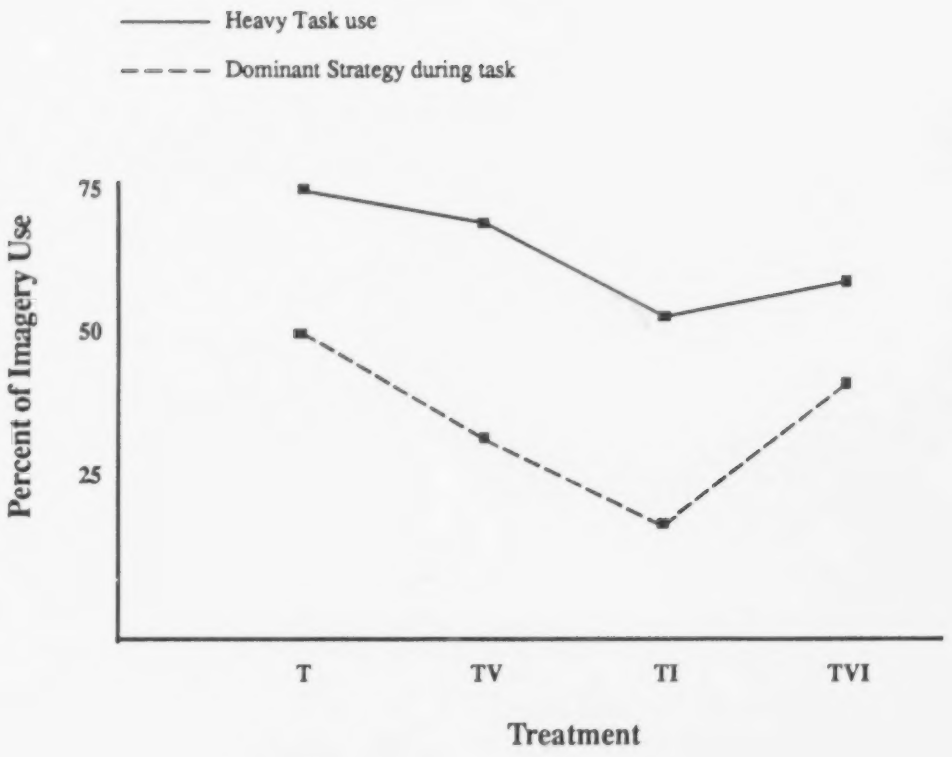


Figure 2. Proportion of Imagery Use During the Task and as a Dominant Strategy.

Table 3

Pearson Correlation Matrix

n=112

	Accretion	Test.	DStrat	Task	Learn.	Other	Accur.	Draw.	Total
Accretion	1.0								
Test time	0.193*	1.0							
Dom Strat	-0.123	-0.019	1.0						
Task use	-0.036	-0.228*	0.155	1.0					
Learning	0.044	-0.006	0.191	0.473**	1.0				
Other use	-0.022	-0.098	0.059	0.383**	0.43**	1.0			
Accuracy	-0.029	-0.15	0.022	0.404**	0.429**	0.387**	1.0		
Drawing	0.267**	-0.11	0.074	0.253*	0.089	0.065	0.12	1.0	
Total Crit.	0.013	-0.002	0.145	0.258**	0.163	0.03	0.22*	0.176	1.0

* $p < 0.05$
** $p < 0.01$

69

memory and therefore generated better images in the visual buffer which facilitated the drawing task.

The subjects who reported the heaviest imagery use during accretion had overall higher scores on the drawing test (r=0.253) and multiple choice tests (r=0.258). These subjects also used imagery heavily during other tasks both in formal learning (r=0.473) and remembering information not related to school (r=0.383). Also, the high imagers felt that they were able to form accurate mental images (r=0.404).

The correlation between those who used imagery in formal learning situations and to remember other information was 0.430. The formal-learning imagers also felt that they formed accurate mental images (r=0.429). The more accurate the images were thought to be, the higher the score on the multiple-choice posttests (r=0.22). Accuracy of imagery and use of imagery in general situations correlated significantly at 0.387.

A negative correlation was found between testing time and task use of imagery (r=-0.228). Subjects who reported using imagery more heavily during the learning task required less time to complete the multiple-choice tests. Faster retrieval time is supported in the research literature. Paivio (1969) reports an experiment in paired-associate learning where imagery instructions resulted in faster mnemonic processing for retrieval.

Chapter Five

SUMMARY AND CONCLUSIONS

This study investigated and reports the effect and use of mental imagery while reading text-based instructional material. Most imagery research involves either paired-associate learning or general imagery instructions with text, where this study used specific imagery instructions embedded in text as an independent variable.

In addition to the imagery instructions, a second independent variable was relevant visual illustrations. The effect of visual illustrations on learning is well researched while the effect of imagery instructions is not.

Four experimental questions and congruent hypotheses (see Chapter One) were formulated from the research literature. In an attempt to learn more about the use of imagery with instructional materials, several dependent measures were collected on each subject. The dependent measures included were three congruent multiple-choice posttests. One of these tests was a visual test of part identification for which mental imagery is considered specialized, since the information is spatially represented on a diagram. The other multiple-choice tests comprised terminology and comprehension questions. A drawing (constructional) test was included since this requires the

subjects to form images in the working memory prior to drawing. Measures of accretion time and testing time were also collected to investigate imagery induction. A questionnaire was used after the treatment to assess the use of imagery during learning.

Results

The present study tested four hypotheses which were derived from the experimental literature. Stated in the null:

H_o: Instructions to form images will produce no difference in the achievement on the criterion posttests.

H_o: Relevant visuals with the text will not interact with imagery instructions.

H_o: Imagery instructions will not effect the results of a constructional task.

H_o: Imagery instructions do not induce the use of imagery during learning.

The results of the present study reinforce the importance of visuals in learning as summarized by Dwyer (1978), Dwyer et al. (1988), and Winn (1989). The analysis of the criterion posttests showed that most of the main effects were produced by the presence of the visual factor, which led to the retention of the first hypothesis.

In addition, a moderate, but nonsignificant interaction was noted between the visuals and imagery on the identification test, which is a visual test requiring

the use of spatial information. This led to the retention of the second hypothesis.

Of all the posttests, the imagery factor produced a significant effect only on the drawing test. Although this significant main effect was not stronger than the visual factor, imagery instructions improved the drawing test scores. Thus the third hypothesis was rejected.

The significant differences in accretion time indicate that, although imagery is widely and heavily used during reading, more extensive use of imagery can be induced. This result led to the rejection of the fourth hypothesis.

Discussion

The subjects in this study were all novices to the subject matter. They did not have the prior knowledge to form focused images in the absence of a concrete visual referent (Bransford, 1982; Stein et al., 1984; Pinker, 1984). This fact was especially evident in the results of the group TI, the group that had the consistently lowest test scores in this study. Although the group TI claimed to use imagery heavily, it was not their dominant strategy.

The imagery factor also produced significant main effects on group TI's accretion time mean. A problem with the accretion time measure is that the instructed groups had approximately 400 extra words to read in their materials in the form of the imagery instructions. This

would obviously require additional reading time. The mean reading rate of group T was 3.19 words per second; therefore, it should take 125.39 seconds for the instructed groups to read the imagery instructions. If the group TI mean is adjusted for instruction reading time, the accretion time mean is only 83.79 seconds more than group T. This may appear to be very little actual imagery time. However, imagery and verbal processes are interrelated and occur simultaneously in a parallel processing system. There is no practical way to separate imaging time from verbal processing time. Attempts to do this would be putting parallel processes in a "serial strait jacket" (Johnson-Laird, 1983). Thus, it is difficult to attribute much meaning to an adjusted accretion time mean, since the subjects could have been imaging as they read the imagery instructions.

The accuracy of the self-reports of imagery use also should be questioned. The use of self-reports in imagery research is summarized by Kosslyn (1980). One of the oldest and most familiar of these is the "breakfast table" questionnaire of Galton's. Although self-reports have been the mainstay of imagery research, self-reports often can be highly inaccurate or exaggerated, which means that the data collected on the questionnaire also may be inaccurate. This fact could explain why that pattern of imagery use in figures 1 and 2 does not seem to reflect the significant differences found in the accretion time measures. The

imagery use pattern in this study supports Long's (1986) finding that imagery is pervasive throughout reading. However, since time is the "hallmark" of imagery use, the more accurate picture of imagery use during learning may well be the more objective accretion time measure.

Several other factors could have impacted the questionnaire results. The subjects in the sample may have been a group of high imagers. Also, the text-based proportion, which was read by all subjects, contains a great deal of spatial information, i.e. detailed descriptions of human heart structure. Spatial information would evoke imagery use and possibly influence the subjects' responses on the questionnaire. In other words, all subjects were exposed to image-evoking material whether or not they were in an instructed group due to the nature of the experimental materials' text.

Visuals evoke both imaginal and verbal encoding of information (Paivio, 1972). Familiar, unambiguous illustrations maximize the availability of both verbal and imaginal processes (Paivio, 1969). Heavy use of imagery in the presence of the visual illustrations is supported by these data (Figures 1 and 2). When visuals are presented, the spatial information is analyzed and processed. In the encoding process, parts of a visual illustration are given verbal labels and are concurrently analyzed by the non-verbal system regarding spatial and temporal relationships. The differences in function between the verbal and non-

verbal system are the basis for Paivio's dual-coding theory.

A picture of dual coding emerges from the questionnaire (Figure 2). Apparently, learners can heavily use imagery although another learning strategy is dominant. Depending on learner characteristics and stimulus variables, learners will use task-specific strategies.

Conclusions

Several conclusions are drawn that are consistent with the research literature. The questionnaire results reaffirm imagery as a cognitive process important to information processing. Imagery is not used to the exclusion of verbal strategies, but it is used concurrently. The fact that imaginal processes can be induced or focused as a strategy to amplify stimuli, facilitate elaboration, selective perception, and encoding for learning is supported by many researchers (Anderson & Kulhavy, 1972 ; Kulhavy & Swenson, 1975; Gagne, 1985; Weinstein & Mayer, 1986), as well as this study.

Conversely, it is difficult to account for the impact of imagery instructions since they arouse verbal mediators, and may increase motivation or interest (Paivio, 1969). The questionnaire data indicated that when both verbal and non-verbal strategies are available, subjects in the present study may have used task-appropriate strategies.

Thus, the subjects' associative strategies are only partly controlled in an experimental situation (Paivio, 1969).

Instructions to form images also significantly improved the results of a constructional (drawing) task. This indicates that imagery is important to the formation of mental representations (Johnson-Laird, 1983). Drawing requires the formation of a visual mental image in the working memory. Although the instructed groups had no visual referent, they were better able to construct a representation of the information.

The significant negative correlation between task use of imagery and testing time is supported in the research literature (Paivio, 1969). Imagery could be useful in training situations where fast information retrieval is important.

The role of imagery instructions seems to be threefold: to cause learners to do more active voluntary processing (Mayer, 1982) and be more involved in learning, facilitating elaboration, to promote the internal conditions of learning and cause additional information processing specific to the learning task, and to facilitate a better understanding of selective qualities, i.e. the spatial and temporal relationships (Kosslyn, 1988; Paivio, 1976).

Implications for Instructional Design

The goal of instructional design theorists is to uncover the cognitive operations used by experts (Aronson & Briggs, 1983). Mental imagery is a type of physical mental model and specialized type of mental representation (Johnson-Laird, 1983). The quality of the mental representation is one of the ways novices and experts differ (Chi, Glaser & Rees, 1981; Gilhooly, 1989; Mayer, 1989).

Since imagery can be important in the formation of mental representations (Kulhavy & Swenson, 1975; Johnson-Laird, 1983), an awareness of imagery and its function could facilitate the acquisition of expertise in many areas. For example, ultrasound radiographers interpret grey-scale output of tissue echogenicity by imposing their image of human anatomy on the ultrasound image. Making the physician aware of imagery use at the beginning of training may contribute to more effective and efficient training of diagnosticians.

The significant negative correlation between imagery use and faster retrieval time may be important in the training of those who need to make split-second decisions and locate controls quickly and accurately.

For traditional instruction, teachers should have an awareness of the nature and function of imagery to help students improve their semantic memory and learning. Imagery instructions can be embedded into traditional

teaching. Students can be told to "picture in their mind" information that is spatial or structural in nature to help them remember it. Also, to maximize the availability of both verbal and imaginal processes, include clear, unambiguous illustrations that are congruent with text (Paivio, 1969).

Of the two independent variables used in this study, the empirical evidence finds that relevant, unambiguous visual illustrations are superior to imagery instructions used alone for facilitating learning of text-based information. Paivio (1969) states that familiar, unambiguous visual illustrations maximize the availability of both verbal and non-verbal cognitive processes, thus promoting dual-coding. Improved mental representations and semantic memory are thought to result from dual coding.

If a choice had to be made between instructional booklets containing either one of the independent variables of this study, the instructional book containing the relevant visual illustrations would be most likely to facilitate learning for more learners. The imagery variable should be used with the visual illustrations when the information or task requirements involve the use of spatial information.

Discussion of Experimental Procedures and Limitations

The recording of accretion time and testing time were self-recorded and were carefully observed by the

investigator. Although the procedure seemed to be satisfactory, future research where these variables are important could use a more sophisticated manner to record the time. The self-recording introduced a source of variability into the data. One method of improving the accuracy of such measures is to make such studies computer based where the times are recorded as a part of the system's log.

The subjects in this study were informed that they would be expected to take criterion posttests after reading the treatment booklet. This could have acted as an advanced organizer and affected the posttest results. If possible, other investigators may be successful in being exempted from this part of informed consent, since only "paper and pencil" tests are involved and subjects are considered to be at minimal risk.

In this study, the subjects received exit interviews only out of curiosity and as time permitted. Also, since some of the sessions involved small groups, exit interviews were not always feasible. Those that were conducted gave a picture of their use of imagery during the treatment. The exit interview was not incorporated into the study since the researcher was inexperienced in this; however, the exit interview could be a valuable source of information in future research.

The results of the survey comprised reports of what the subjects believed to be true. Although self-reports

are heavily used in many areas of research including imagery, the results may be inaccurate and contain a response bias.

The sample itself was drawn from undergraduates from the same class. Although the cells ultimately had equal proportions of males and females, it is possible that the sample is not as representative of the undergraduate population as it could have been, since the males were under-represented.

Recommendations for Future Research

Research is needed to gain more knowledge about imagery as a cognitive process, mnemonic strategy, and instructional variable. Some suggestions for further research are offered below.

1. To see if mental imagery could improve information acquisition for novices, the quality of the mental representation could be studied in a series of experiments similar to those summarized in Chi, Glaser and Rees (1981) where experts and novices are compared.

2. According to O'Brien and Wolford (1982), imagery instructions may interfere with personal encoding and cause subjects to produce images with less meaning than their own images. To investigate the effect of imagery instructions on personal encoding, a study could be done with three treatment groups: no imagery, general imagery instructions,

and focused imagery instructions. This study also could be done with two levels of the visual factor.

3. Future studies should investigate the effect of imagery on long-term retention.

4. The significant effect of the imagery factor on the identification test, which is a type of visual test, should be investigated further using a visual criterion test as well as a verbal test. Such a strategy would have been attempted in this study if a larger pool of subjects had been available.

5. The induction of imagery seems tenable. More studies into the accretion stage should be done, both to understand the chunking process of the learner and to understand the instructional variables that are most effective and efficient for instruction.

6. Finally, the possibility of an interaction effect with stimulus variables should be investigated since there was a moderate interaction in this study, although it was not significant. The dual-coding theory indicates that a significant interaction is highly probable, especially with spatial information.

REFERENCES

Ahsen, A. (1985) Image psychology and the emperical method. Journal of Mental Imagery, 9(2), 1-40.

Anderson, J. R. and Bower, G.H. (1973) Human Associative Memory. Washington, DC: Winston.

Anderson, R.C. (1970) Control of student mediating processes during verbal learning and instruction. Review of Educational Research, 40(3), 349-369.

Anderson, R.C. and Kulhavy, R. W. (1971) Imagery and sentence learning. Journal of Educational Psychology, 62(3), 526-530.

Anderson, R.E. (1982) Speech imagery is not always faster than visual imagery. Memory and Cognition, 10(4), 371-380.

Annis, L. F. (1979) Effect of cognitive style and learning passage organization on study technique effectiveness. Journal of Educational Psychology, 71(5), 620-626.

Antonietti, A., Barolo, E., Masini, R. (1985) Requirements of the structure, mental figural synthesis, and problem solving. Ricerche-di-Psicologia, 9(1), 97-125.

Aronson, D.T. and Briggs, L.J. (1983) Contribution of Gagne and Briggs to a prescriptive model of instruction. In C. M. Reigeluth, ed., Instructional Design Theories and Models: An Overview of their Current Status. Hillsdale, NJ: Lawrence Earlbaum Assoc.

Ausburn L.J. and Ausburn, F.B. (1978) Cognitive styles: Some information and implications for instructional design. Educational Communications and Technology Journal, 26(4), 337-354.

Aususbel, D.P. (1978) In defense of advanced organizers: A reply to the critics. Review of Educational Research, 48, 251-57.

Beritshivili, I. S. (1969) Concerning psychoneural activity of animals. In Cole, M. and Maltzman, E. (eds): A handbook of contemporary Soviet psychology. New York: Basic.

Bower, G.H. (1970) Anaylsis of a mnemonic device. American Scientist, 58, 496-510.

Bower, G.H. and Hilgard, E.R. (1981) Information-processing theories of behavior. In G.H. Bower and E.R. Hilgard Theories of Learning (5th ed., pp. 353-415). Englewood Cliffs, NJ: Prentice-Hall.

Bower, G.H. and Winzenz, D. (1970) Comparison of associative learning strategies. Psychonomic Science, 20(2), 119-120.

Bransford, J.D., Stein, B.S., Vye, N.J., Franks, J.J., Auble, P.M., Mezynski, K.J., and Perfetto, G.A. (1982) Differences in approaches to learning: an overview. Journal of Experimental Psychology: General, 111(4), 390-398.

Breuer, J. and Freud, S. (1955) Studies on Hysteria. Stand Education, 2.

Brezin, M.J. (1980) Cognitive monitoring: from learning theory to instructional applications. Educational Communications and Technology Journal, 28(4), 227-242.

Briggs, L.J. (1981) Instructional Design. Englewood Cliffs, NJ: Educational Technology Publications.

Bucci, W. (1984) Linking words and things: Basic processes and individual variation. Cognition, 17, 137-153.

Campbell, D.T. and Stanley, J.C. (1966) Experimental and Quasi-Experimental Designs for Research. Chicago: Rand McNally Publishing Co.

Carrier, C., Joseph, M.R., Krey, C.L., and LaCroix, P. (1983) Supplied visuals and imagery instructions in field independent and field dependent children's recall. Educational Communications and Technology Journal, 31(3), 153-160.

Chi, M.T.H., Glaser, R., and Rees, E. (1981) Experitse in problem solving (Technical Report #5). Pittsburgh, PA: University of Pittsburgh.

Denis, M. and Carfantan, M. (1985) People's knowledge about images. Cognition, 20, 49-60.

Dillingofski, M.S. (1980) The effects of imposed and induced visual imagery strategies on ninth grade difference-poor readers' literal comprehension of concrete and abstract prose. Unpublished doctoral dissertation, University of Wisconsin.

Di Vesta, F.J. (1975) Trait-treatment interactions, cognitive processes, and research on communications media. AV Communication Review, 23(2), 185-196.

Di Vesta, F.J. and Bartoli, A. (1982) The relation of field dependence to signal detection while imaging. Perception and Psychophysics, 31(3), 219-226.

Di Vesta, F. J., Ingersoll, G. and Sunshine, P. (1971) Factor analysis of imagery tests. Journal of Verbal Learning and Verbal Behavior, 10, 471-479.

Di Vesta, F.J. and Ross, S. M. (1971) Imagery ability, abstractness, and word order as variables in recall of adjectives and nouns. Journal of Verbal Learning and Verbal Behavior, 10, 686-693.

Di Vesta, F.M. and Ross, S.M. (1978) The effects of imagery ability and context saliency on the semantic interpretation of verbal stimuli. Journal of Mental Imagery, 2, 187-198.

Di Vesta, F.J. and Finke, F.M. (1985) Metacognition, elaboration and knowledge acquisition: implications for instructional design. Educational Communications and Technology Journal, 33(4), 285-293.

Doob, L.W. (1972) The ubiquitous appearance of images. In The function and nature of imagery, P.W. Sheehan, ed. New York: Academic Press.

Dwyer, F. M. (1978) Strategies for Improving Visual Learning. State College, PA: Learning Services, Inc.

Dwyer, F.M., Dwyer, C.A., and Canelos, J.C. (1988) Enhancing Visualized Instruction. Paper presented at the Twentieth Annual Conference of the International Visual Literacy Association, Blacksburg, VA, October 19-23.

Edelstein, R.A. (1981) The effects of verbal and visual elaborations on the learning of abstract concepts. Unpublished doctoral dissertation. University of California at Los Angeles.

Einstein, G.O., McDaniel, M.A., and Lackey, S. (1989) Bizarre imagery, interference and distinctiveness. Journal of Experimental Psychology: Learning Memory and Cognition, 15(1), 137-146.

Estes, W. K. (1978) Handbook of Learning and Cognitive Processes, Vol. 5. Hillsdale, NJ: Lawrence Erlbaum Assoc.

Eysenck, M.W. (1989) Human learning. In Human and Machine Problem Solving, New York, New York: Plenum.

Farah, M.J. (1984) The neurological basis of mental imagery: A componential analysis. Cognition, 18, 245-272.

Farah, M.J. (1989a) Semantic and perceptual priming: How similar are the underlying mechanisms? Journal of Experimental Psychology: Human Perception and Performance, 15(1), 188-194.

Farah. M.J. (1989b) Mechanisms if the imagery-perception interaction. Journal of Experimental Psychology: Human Perception and Performance, 15(2), 203-211.

Finke, R.A., Pinker, S., and Farah, M.J. (1989) Reinterpreting visual patterns in mental imagery. Cognitive Science, 13, 51-78.

Frank, B. M. (1986) Cognitive styles and teacher education: Field dependence and areas of specialization among teacher education majors. Journal of Educational Research, 80(1), 19-22.

Frost, N. (1972) Encoding and retrieval in visual memory tasks. Journal of Experimental Psychology, 95(2), 317-326.

Gagne, E.D. (1985) The Cognitive Psychology of School Learning. Boston: Little, Brown and Co.

Gilhooly, K.J. (1989) Human and machine problem solving: A comparative view. In Human and Machine Problem Solving, New York, New York: Plenum.

Gronlund, N.E. (1985) Measurement and evaluation in teaching, fifth ed. New York: Macmillan Publishing Co.

Hanawalt, G. (1954) Recurrent Images: New instances and a summary of the older ones. American Journal of Psychology, 67, 170-74.

Hitch, G.J., Woodin, M.E., and Baker S. (1989) Visual and phonological components of working memory in children. Memory and Cognition, 17(2), 175-185.

Horowitz, M. J. (1983) Image formation and psychotherapy. New York: Jason Aronson.

Hubbard, I.L., Kall, D., and Baird, J.C. (1989) Imagery, memory and size-distance invariance. Memory and Cognition. 17(6), 87-94.

Johnson-Laird, P.N. (1983) Mental Models. Cambridge, MA: Harvard University Press.

Jonassen, D.H. (1979) Cognitive styles/controls and media. Educational Technology, 19, 28-32.

Jung, C.J. (1955) The Archetypes and the Collective Unconcious. New York: Pantheon.

Kaufman, G. (1984) Mental imagery in problem solving. In A.N. Sheikh ed., International Review of Mental Imagery, New York, New York: Human Services Press, Inc.

Kaufman, G. (1985) A theory of symbolic representation in problem solving. Journal of Mental Imagery, 9(2), 51-70.

Kiewra, K. A. and Frank, B. M. (1988) Encoding and external-storage effects of personal lecture notes, skeletal notes, and detailed notes for field-independent and field-dependent learners. Journal of Educational Research, 81(3), 143-148.

Kosslyn, S. M., Brunn, J, Cave, K. R., and Wallach, R. W. (1984) Individual differences in mental imagery ability: a computational analysis. Cognition, 18, 195-243.

Kosslyn, S.M., Cave, C.B., Provost, D.A., and von Gierke, S.M. (1988) Sequential processes in image generation. Cognitive Psychology, 20(3), 319-343.

Kosslyn, S.M., Reiser, B.J., Farah, M.J., Fliegel, S.L. (1983) Generating visual images. Journal of Experimental Psychology: General, 112(2), 278-303.

Kosslyn, S.M. (1980) Image and mind. Cambridge, MA: Harvard University Press.

Kosslyn, S. M. (1981) The medium and the message in mental imagery: a theory. Psychological Review, 88(1), 46-66.

Kosslyn, S.M. (1988) Aspects of a cognitive neuroscience of mental imagery. Science, 240, 1621-1626.

Kozma, R.B. (1986) Implications of instructional psychology for the design of educational television. Educational Communications and Technology Journal, 34(1), 11-19.

Kulhavy, R.W. and Swenson, I. (1975) Imagery instructiona and the comprehension of text. British Journal of Educational Psychology. 45, 47-51.

Lamberski, R.J. (1980) The effect of a verbal and visual color code on self-paced instruction and testing for retention on different tasks. Unpublished Doctoral Dissertation, The Pennsylvania State University.

Larkin, J.H. and Simon, H.A. (1987) Why a diagram is (sometimes) worth ten thousand words. Cognitive Science, 11, 65-69.

Levie, W.H., and Levie, D. (1975) Pictoral memory process. AV Communication Review, 23(1), 81-97.

Levin, J. (1983) Pictorial strategies for school learning: Practical illustrations. In Cognitive Strategy Research: Educational Applications. M. Pressley and J. Levin, eds. New York: Springer-Verlag.

Lindauer, M.S. (1972) "The sensory attributes and function of imagery and imagery-evoking stimuli." In The function and nature of imagery, P.W. Sheehan, ed. New York: Academic Press.

Lindsay, R.K. (1988) Images and inference. Cognition, 29, 229-250.

Long, S.A. (1986) The effects of reader and text characteristics on reports of imagery during reading. Unpublished doctoral dissertation. University of Kentucky.

Luria, A.R. (1966) Higher cognitive functions in man. New York: Basic.

Marks, D.M. (1972) "Individual Differences in the vividness of visual imagery and their effect on function." In The function and nature of imagery, P.W. Sheehan, ed. New York: Academic Press.

Marks, D.M. (1985) Imagery paradigms and methodology. Journal of Mental Imagery, 9(2), 93-106.

Mayer, R.E. (1984) Aids to text comprehension. Educational Psychologist, 19(1), 30-42.

Mayer, R.E. (1987) Educational Psychology. Boston: Little, Brown and Co.

Mayer, R.E. (1989) Human Nonadversary Problem Solving. In K.J. Gilhooly, ed., Human and Machine Problem Solving. New York, New York: Plenum.

McDaniel, M.A. and Kearney, E.M. (1984) Optimal learning strategies and their spontaneous use: The importance of task-appropriate processing. Memory and Cognition, 12(4), 361-373.

McGee, M.G. (1979) Human Spatial Abilities. New York: Praeger Publishers.

McGee, M.G. (1982) Spatial abilities: The influence of genetic factors. In M. Potegal, ed., Spatial Abilities. New York: Academic Press.

McIntosh, W.J. (1984) The effects of augumenting physical science rules by imaging prototypic examples of subordinate concepts. Unpublished doctoral dissertation. Temple University.

McKean, K. (1983) Memory. Discover, 4(11), 18-28.

Miller, G. A. (1956) The magical number seven plus or minus two: Some limits in our capacity for processing information. Psychological Review, 63(2), 81-97.

Myers, J. L. (1979) Fundamentals of experimental design, third edition. Boston: Allyn Bacon, Inc.

Neisser, U. (1972) "Changing conceptions of imagery." In The function and nature of imagery, P.W. Sheehan, ed. New York: Academic Press.

Norman, D. A. (1980) What goes on in the mind of the learner. In Learning, Cognition and College Teaching, W.J. McKeachie, ed. Washington: Jossey-Bass, Inc.

O'Brien, E. J. and Wolford, C. R. (1982) Effect of delay in testing on retention of plausible versus bizarre mental images. Journal of Experimental Psychology, 8(2), 148-152.

Olson, D. R., and Bialystock, E. (1983) Spatial Cognition. Hillsdale, NJ: Lawrence Erlbaum Associates.

Paivio, A. (1969) Mental imagery in associative learning and memory. Psychological Review, 76(3), 241-263.

Paivio, A. (1971) Imagery and verbal processes. New York: Holt, Reinhart and Winston.

Paivio, A. (1972) "A theoretical analysis of the role of imagery in learning an memory." In The function and nature of imagery, P.W. Sheehan, ed. New York: Academic Press.

Paivio, A. (1975) Perceptual comparisons through the mind's eye. Memory and Cognition, 3(6), 635-647.

Perkins, D.N. and Salomon, G. (1989) Are cognitive skills context-bound? Educational Researcher, 16-25.

Pinker, S. (1984) Visual cognition: An introduction. Cognition, 18, 1-63.

Pompi, K. F. and Lachman, R. (1967) Surrogate processes in the short-term retention of connected discourse. Journal of Experimental Psychology, 75(2), 143-150.

Posner, M.I. (1973) Cognition: An Introduction. Glenview, IL: Scott, Foresman and Co.

Pylyshyn, Z. W. (1981) The imagery debate: Analogue media versus tacit knowledge. Psychological Review, 88(1), 16-45.

Reese, H.W. (1977) Toward a cognitive theory of mnemonic imagery. Journal of Mental Imagery, 2, 229-244.

Reigeluth, C.M. (1983) Instructional Design Theories and Models: An Overview of Their Current Status. Hillsdale, NJ: Lawrence Earlbaum Assoc.

Reimann P. and Chi, M.T.H. (1989) Human Expertise. In K.J. Gilhooly, ed., Human and Machine Problem Solving. New York, New York: Plenum.

Richardson, A. (1972) Voluntary control of the memory image. In The function and nature of imagery, P.W. Sheehan, ed. New York: Academic Press.

Roth, J.D. and Kosslyn, S.M. (1988) Construction of the third dimension in mental imagery. Cognitive Psychology, 20(3), 344-361.

Runquist, W. N. and Hutt, V.H. (1961) Verbal concept learning in high school students with pictorial and verbal representation stimuli. Journal of Educational Psychology, 52(1), 108-111.

Ryerson, N. (1982) Using and creating visual images: a new task for rehabilitation? Journal of Visual Impairment and Blindness, 76(10), 421-423.

Severin, W. (1967) Another look at cue summation. AV Communication Review, 15, 233-245.

Shepard, R. N. (1978) The mental image. American Psychologist, 33(1), 125-137.

Shepard, R.N. and Podgarny, P. (1978) "Cognitive processes that resemble perceptual processes." In W. K. Estes, ed., Handbook of learning and cognitive processes (vol. V). Hillsdale, NJ; Lawrence Earlbaum.

Stein, B.S., Bransford, J.D., Franks, J.J., Owings, R.A., Vye, N.J., and McGraw, W. (1982) Differences in the precision of self-generated elaborations. Journal of Experimental Psychology: General, 111(4), 399-405.

Stein, B.S., Littlefield, J., Bransford, J.D., and Persampieri, M. (1984) Elaboration and knowledge acquisition. Memory and Cognition, 12(5), 522-529.

Travers, R.M.W. (1982) Essentials of Learning, 5th edition. New York: Macmillan Publishing Co., Inc.

Tversky, B. (1973) Encoding processes in recognition and recall. Cognitive Psychology, 5, 275-287.

Ullman, S. (1984) Visual routines. Cognition, 18, 97-159.

Weinstein, C.E. and Mayer R.E. (1986) The teaching of learning strategies. In Handbook of Research on Teaching, Wittrock, ed. Chicago: Rand McNally.

Wicker, F.W., Weinstein, C.E., Yelich, C.A., and Brooks, J.D. (1978) Problem-reformulation training and visualization training with insight problems. Journal of Educational Psychology, 70(3), 372-377.

Winn. W. (1989) The role of graphics in training documents: toward an explanatory theory of how they communicate. IEEE Transactions on Professional Communications, 32(4), 300-309.

Appendix A

INFORMED CONSENT FORM AND INSTRUCTIONS TO THE SUBJECTS

Informed Consent form

Title of Investigation: The effectiveness of imaginal processes as a cognitive strategy on learning and achievement

Investigators: Carol L. Hodes, M.S.; and Paul W. Welliver, Ph.D.

Date: September 1989

This is to certify that I, _____, hereby agree to participate as a volunteer in a scientific investigation as an authorized part of the education and research program of the Pennsylvania State University under the supervision of Dr. Paul W. Welliver.

The investigation and my part in the investigation have been defined and fully explained to me by Carol L. Hodes or her representative, and I understand her explanation. A copy of the procedures of this investigation and a description of any risks and discomforts has been provided to me and has been discussed in detail with me.

I have been given the opportunity to ask whatever questions I may have had and all such questions and inquiries have been answered to my satisfaction.

I understand that I am free to deny any answers to specific items or questions in interviews or questionnaires.

I understand that any data or answers to questions will remain confidential with regard to my identity.

I FURTHER UNDERSTAND THAT I AM FREE TO WITHDRAW MY CONSENT AND TERMINATE MY PARTICIPATION AT ANY TIME.

_____ _____
Date Subject's signature

I, the undersigned have defined and fully explained the investigation to the above subject.

_____ _____
Date Investigator's Signature

Instructions to subjects (no imagery, treatments 1 and 2)

You are participating in a study which is designed to increase our basic understanding about learning strategies. You are receiving one of four instructional modules used in this study.

The subject matter is about the parts and function of the human heart. After reading, you will be asked to answer a questionnaire, take a drawing test and a multiple-choice test. After at approximately 100 volunteers have finished the tests, the researcher will look at the overall group scores on the time, questionnaire results and the test scores to compare the effectiveness of the different modules. Your student number is being collected only to match the answer sheets if they should become separated.

Please do your best on the tests. You may proceed at your own rate. There are places for you to record the time you begin and end for both the reading and the testing.

If you have any additional questions about this study, please contact the researcher, Carol L. Hodes, at 863-2133, or leave a message and she will return your call.

Instructions to subjects ("imagery" treatments 3 and 4)

You are participating in a study which is designed to increase our basic understanding about learning strategies. You are receiving one of four instructional modules used in this study.

The subject matter is about the parts and function of the human heart. As you read, instructions to form pictures in your mind will appear at the bottom of each page. Try to form these pictures in your mind as instructed before turning the page and going on.

To practice forming the mental pictures before you start to read, visualize a heart--something that looks like a heart-shaped valentine--in your mind. Since the human heart has four chambers, next visualize the heart divided into four quadrants.

After reading, you will be asked to answer a questionnaire, take a drawing test and a multiple choice test. After at approximately 100 volunteers have finished the tests, the researcher will look at the overall group scores on the time, questionnaire results and the test scores to compare the effectiveness of the different modules. Your student number is being collected only to match the answer sheets if they should become separated.

Please do your best on the tests. You may proceed at your own rate. Some of the other participants may complete the treatment and tests earlier than others, and will be leaving the room. This is expected and does not relate to the ability of any of the participants.

There are places for you to record the time you begin and end for both the reading and the testing.

If you have any further questions about this study please contact the researcher, Carol L. Hodes, at 863-2133, or leave a message and she will return your call.

Time-Recording Sheet

module _____

Please record the following:

_____ student number

_____ time beginning reading

_____ time reading completed

_____ time testing begun

_____ time tests completed

Appendix B

POSTTREATMENT QUESTIONNAIRE

	Not at All				Heavily Used
	(circle closest number)				
1. I formed pictures in my mind during this task.	1	2	3	4	5
2. I often construct mental pictures in formal learning situations	1	2	3	4	5
3. I often construct mental pictures when trying to remember information not related to school	1	2	3	4	5
4. I feel that I am able to form accurate mental pictures	1	2	3	4	5

5. What, if any, was your dominant means of learning during this task? (circle one)

a. repeating information over and over

b. forming mental pictures

c. forming associations between words

d. attempting to construct a summary of the information and ideas, such as forming

Appendix C

PILOT STUDY DATA AND ITEM ANALYSIS

Pilot n = 19

Total Criterion Mean = 34.8, s.d. = 5.899

Identification Test = 12.4, s.d. = 3.05

Terminology Test Mean = 11.6, s.d. = 3.782

Comprehension Test Mean = 10.8, s.d. = 3.899

Item #	Percentage correct	Item #	Percentage Correct
1.	58	31.	47
2.	58	32.	63
3.	5	33.	68
4.	53	34.	42
5.	53	35.	89
6.	47	36.	63
7.	42	37.	53
8.	47	38.	47
9.	84	39.	47
10.	79	40.	63
11.	53	41.	79
12.	74	42.	53
13.	53	43.	79
14.	68	44.	58
15.	74	45.	37
16.	53	46.	16
17.	37	47.	63
18.	37	48.	63
19.	53	49.	58
20.	42	50.	63
21.	58	51.	63
22.	68	52.	32
23.	58	53.	32
24.	58	54.	63
25.	53	55.	26
26.	58	56.	37
27.	84	57.	32
28.	37	58.	11
29.	58	59.	37
30.	63	60.	42

Appendix D

EXPERIMENTAL MATERIALS

The Heart And Its Functions

The human heart is a hollow, bluntly conical, muscular organ. Its pumping action provides the force that circulates the blood through the body. In the average adult, the heart is about five inches long and about two and one half inches thick. A man's heart weighs about eleven ounces and a woman's heart weighs about nine ounces.

The heart lies toward the front of the body and is in a slanting position between the lungs, immediately below the breastbone. The wide end points toward the right shoulder. The small end of the heart points downward to the front of the chest and toward the left. The lower portion of the heart is called the apex and is the part that you feel beating.

In order to better comprehend the following instruction, it will be helpful to visualize a cross-section view of a human heart in a position such that you are facing the person. As you visualize it, the right side of the heart will be on the left side.

To understand the functioning of the heart you will need to be able to identify the parts of the heart. The heart is enclosed in a thin double-walled sac. The layer which forms the outer wall of the sac is called the pericardium. It is composed of a tough, transparent, elastic tissue. It protects the heart from rubbing against the lungs and the walls of the chest. The inner portion of the double walled sac is called the epicardium. It is attached to the heart muscle.

The heart muscle is called the myocardium; it controls the contraction and relaxation of the heart. The myocardium constitutes by far the greatest volume of the heart and its contraction is responsible for the propulsion of the blood throughout the body. The myocardium varies in thickness. For example, the myocardium forming the auricle walls is thin when compared to the thickness of the myocardium forming the ventricle walls.

The endocardium is the name given to the inside lining of the heart wall.

The human heart is really two pumps combined into a single organ which circulates blood to all parts of the body. The heart is divided longitudinally into two halves by the septum. The two halves may be compared to a block of two houses, which are independent of each other but have a common wall, the septum, between them.

Each half of the heart is divided into an upper chamber and a lower chamber; the upper chambers are called auricles and the lower chambers are called ventricles. Although there is no direct communication between the right and left sides of the heart, both sides function simultaneously. As was stated previously, the upper chambers on each side of the septum are auricles, and the lower chambers are called ventricles. Auricles have thin walls and act as receiving rooms for

the blood while the ventricles below act as pumps, moving the blood away from the heart.

As you would view a cross-sectional diagram of the heart, blood enters the right auricle through veins. Only veins carry blood to the heart. The superior and inferior vena cavas are the two veins which deposit blood in the right auricle. There are no valves at the openings of these veins. The superior vena cava deposits blood into the right auricle from all body parts above heart level. for example, the head and the arms.

The other vein, the inferior vena cava, deposits blood into the right auricle from the trunk and legs–that is, from regions below the heart level. As blood from the body fills the right auricle, come of it begins to drip into the right ventricle immediately.

The auricles and ventricles on each side of the heart communicate with each other through openings. The opening between the right auricle and right ventricle is called the tricuspid valve. This valve consists of three triangular flaps of thin, strong, fibrous tissue. These flaps permit the flow of blood into the right ventricle, but prevent it from flowing backward into the right auricle because the ends of the flaps are anchored to the floor of the right ventricle by slender tendons.

The three flaps act like swinging doors which open only in one direction. Thus, blood passes from the right auricle through the tricuspid valve into the right ventricle. As soon as the right ventricle is filled with blood, both ventricles begin to contract.

The first effect of the pressure produced in the right ventricle is to force blood behind the flaps of the tricuspid valve.

While the blood pressure behind the flaps brings the flaps together and prevents the flow of blood, the contraction of the right ventricle continues until the blood presses hard enough to open the pulmonary valve and to force the blood into the pulmonary artery. The pulmonary valve is located between the right ventricle and the pulmonary artery.

The pulmonary valve, like the tricuspid valve, consists of three flaps which fill with blood backing up in the pulmonary artery. as soon as the right ventricle begins to relax from its contraction, the pulmonary valve prevents blood from flowing back into the right ventricle from the pulmonary artery. The pulmonary valve opens only when the pressure in the right ventricle is greater than the pressure in the pulmonary artery, forcing the blood into the pulmonary artery.

The pulmonary valve is composed of flaps or pockets, which the swollen pulmonary artery quickly fill with blood as soon as the right ventricle begins to relax from its contraction. The flaps or pockets of the valve are thus pressed together, and no blood flows back into the right ventricle.

After the blood passes through the pulmonary valve it enters the pulmonary artery, from which it is carried up through the heart to both the left and right lungs where it is cleansed and oxygenated.

Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle.

Like the right auricle, the left auricle also contracts when it is full, squeezing blood through the mitral valve into the left ventricle. The mitral valve is located between the left auricle and the left ventricle.

The mitral valve is similar in construction to the tricuspid valve. As the left ventricle contracts simultaneously with its mate, the right ventricle, it forces blood behind the flaps of the mitral valve, thereby closing the path back to the left auricle.

The contraction of the left ventricle pumps the blood through the entire body. For this reason it is the largest, strongest, and most muscular section of the heart. When the left ventricle which is filled with blood contracts, the resulting pressure in the ventricle opens the aortic valve located in the mouth of the aorta.

The aorta is the large artery which carries the blood from the left ventricle.

The circulation of the blood

The directional flow of blood in the heart is determined by valves which allow the blood to flow in only one direction.

Both auricles receive blood simultaneously through unguarded openings in the veins. The right auricle receives its blood through the superior and inferior vena cavas while the left auricle receives its blood through the pulmonary veins.

A wave of muscular contractions starts at the top of the heart and passes downward, simultaneously over both sides of the heart; that is, both auricles contract at the same time and then relax as the contraction passes down to the ventricles. When the auricles are caused to contract, they become small and pale, and in doing so the blood in their chambers is subjected to increased pressure which forces blood through both the tricuspid and mitral valves.

As the ventricles fill, eddies of the blood float the flaps on both the tricuspid and mitral valves out to a partly closed position.

As the ventricle pressure becomes greater than that in the auricles, the valves are tightly closed and so prevent blood from being forced backward into the auricles.

While the auricles are relaxing from the contraction, blood flows into them from the veins as the contraction of the ventricles is initiated.

The instant that the contraction of the auricles has been completed, the ventricles are stimulated to contract; this contraction increases the pressure in the chambers, forcing the valves, both the tricuspid and mitral, completely shut.

The pulmonary valve and the aortic valve, also called the semilunar valves, that guard the entrances to the pulmonary artery on the right and the aortic artery on the left are closed by the back pressure provided by the blood already in these vessels. When the ventricle pressure becomes greater than that in the exit vessels, the pulmonary and aortic valves open.

Blood flows from the right ventricles into the pulmonary artery en route to the lungs and from the left ventricle into the aorta for distribution through the entire body.

Immediately following ejection of the blood into the arteries, the ventricles begin to relax; this lowers the pressure within their chambers, and the greater pressure in the arteries closes the semilunar valves. Pressure within the ventricles is sufficient, however, to maintain closure of the tricuspid and mitral valves against the already increasing auricle pressure.

As the ventricles relax further, pressure within them decreases correspondingly, and the tricuspid and mitral valves are forced open by

the increased auricle pressure caused by blood flowing into them from the veins. Therefore, before the next auricle contraction, blood is already flowing from the auricles into the ventricles because a greater blood pressure exists in the auricles than in the ventricles.

The cycle of the heartbeat consists of two parts

The relaxation of the ventricles, during which they are filled with blood, is called the diastolic phase.

The heart relaxes between beats in the diastolic phase. Blood flows into the heart filling both auricles. While the blood is flowing into the auricles, the recoil of the artery wall still maintains part of the pressure developed by the contraction of the ventricles. This is the time of the lowest pressure in the arteries or what is called diastolic pressure.

The contraction phase or systolic phase begins when the auricles contract. The blood forces its way through the mitral and tricuspid valves into the ventricles.

The ventricles contract and force the blood through semilunar valves, that is, the pulmonary and aortic valves.

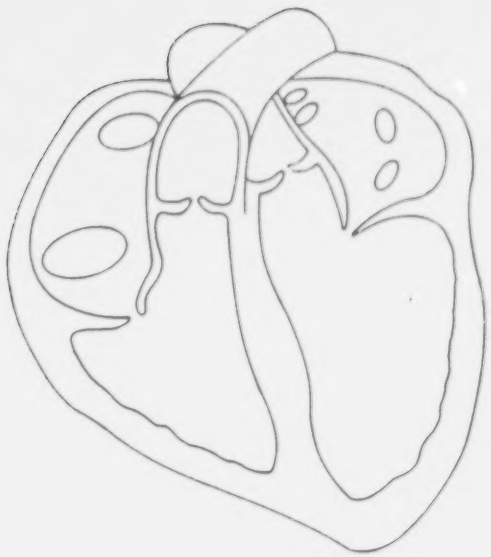
After passing through the pulmonary and aortic valves, the blood enters the pulmonary and aortic arteries. The blood leaves the ventricles under terrific pressure and surges through the arteries with a force so great that it bulges their elastic walls. At this point, arterial blood pressure is the greatest; this pressure is called systolic pressure. The heart relaxes again and the tricuspid and mitral valves close. Blood flows into the auricles; the mitral and tricuspid valves are forced open, and the cycle begins again.

The human heart is a hollow, bluntly conical, muscular organ. Its pumping action provides the force that circulates the blood through the body. In the average adult, the heart is about five inches long and about two and one half inches thick. A man's heart weighs about eleven ounces and a woman's heart weighs about nine ounces.

The heart lies toward the front of the body and is in a slanting position between the lungs, immediately below the breastbone. The wide end points toward the right shoulder. The small end of the heart points downward to the front of the chest and toward the left. The lower portion of the heart is called the apex and is the part that you feel beating.

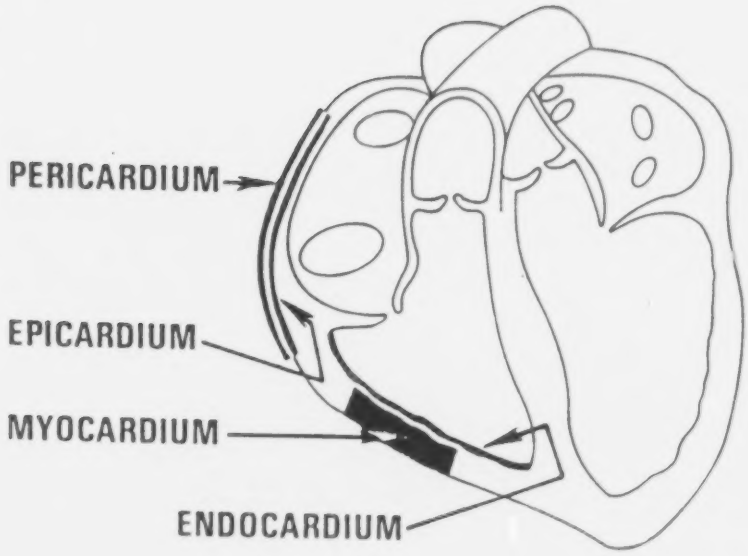
RIGHT
SIDE

LEFT
SIDE



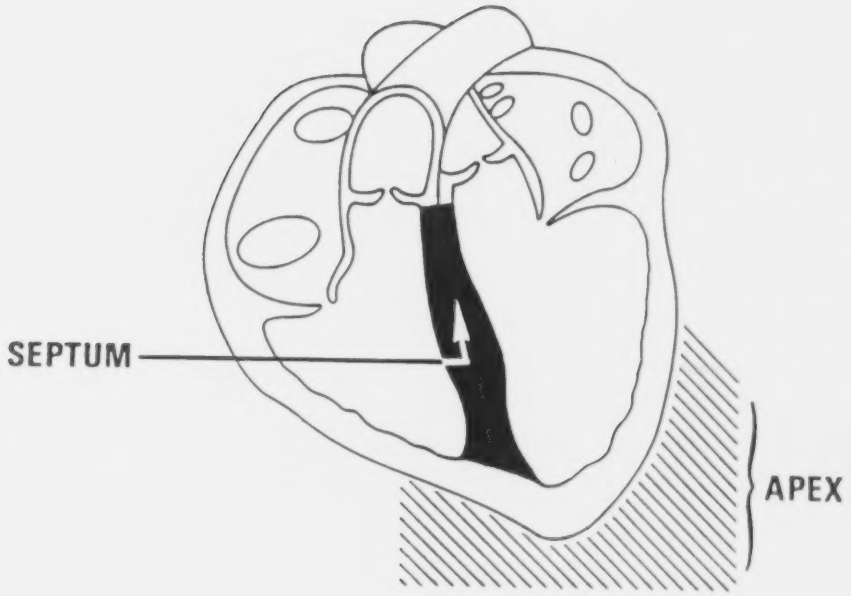
In order to better comprehend the following instruction, it will be helpful to visualize a cross-section view of a human heart in a position such that you are facing the person. As you visualize it, the right side of the heart will be on the left side.

To understand the functioning of the heart you will need to be able to identify the parts of the heart. The heart is enclosed in a thin double-walled sac. The layer which forms the outer wall of the sac is called the pericardium. It is composed of a tough, transparent, elastic tissue. It protects the heart from rubbing against the lungs and the walls of the chest. The inner portion of the double walled sac is called the epicardium. It is attached to the heart muscle.

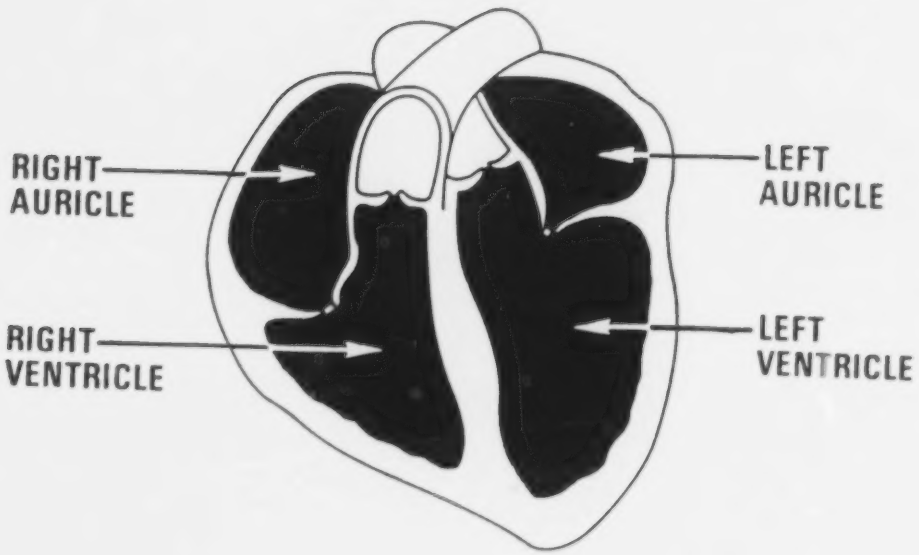


The heart muscle is called the myocardium; it controls the contraction and relaxation of the heart. The myocardium constitutes by far the greatest volume of the heart and its contraction is responsible for the propulsion of the blood throughout the body. The myocardium varies in thickness. For example, the myocardium forming the auricle walls is thin when compared to the thickness of the myocardium forming the ventricle walls.

The endocardium is the name given to the inside lining of the heart wall.



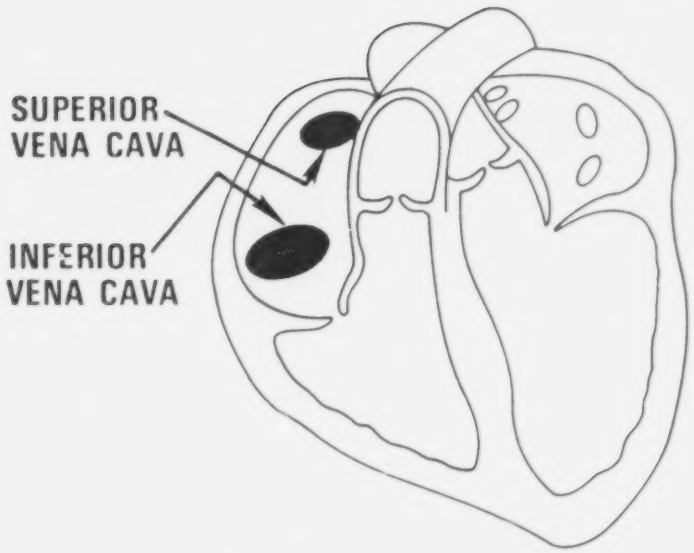
The human heart is really two pumps combined into a single organ which circulates blood to all parts of the body. The heart is divided longitudinally into two halves by the septum. The two halves may be compared to a block of two houses, which are independent of each other but have a common wall, the septum, between them.



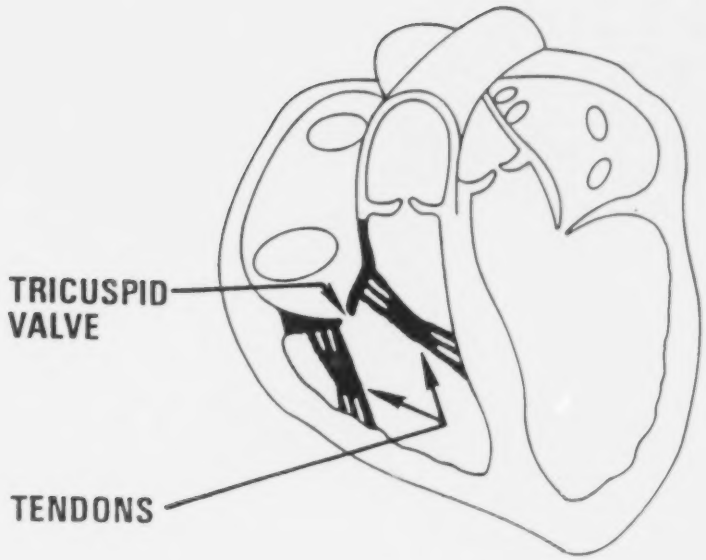
Each half of the heart is divided into an upper chamber and a lower chamber; the upper chambers are called auricles and the lower chambers are called ventricles. Although there is no direct communication between the right and left sides of the heart, both sides function simultaneously. As was stated previously, the upper chambers on each side of the septum are auricles, and the lower chambers are called ventricles. Auricles have thin walls and act as receiving rooms for the blood while the ventricles below act as pumps, moving the blood away from the heart.

As you would view a cross-sectional diagram of the heart, blood enters the right auricle through veins. Only veins carry blood to the heart. The superior and inferior vena cavas are the two veins which deposit blood in the right auricle. There are no valves at the openings of these veins. The superior vena cava deposits blood into the right auricle from all body parts above heart level, for example, the head and the arms.

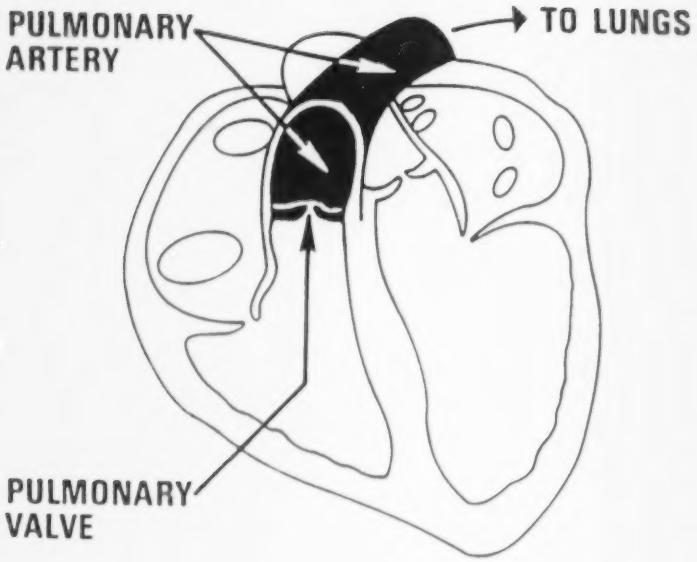
The other vein, the inferior vena cava, deposits blood into the right auricle from the trunk and legs–that is, from regions below the heart level.



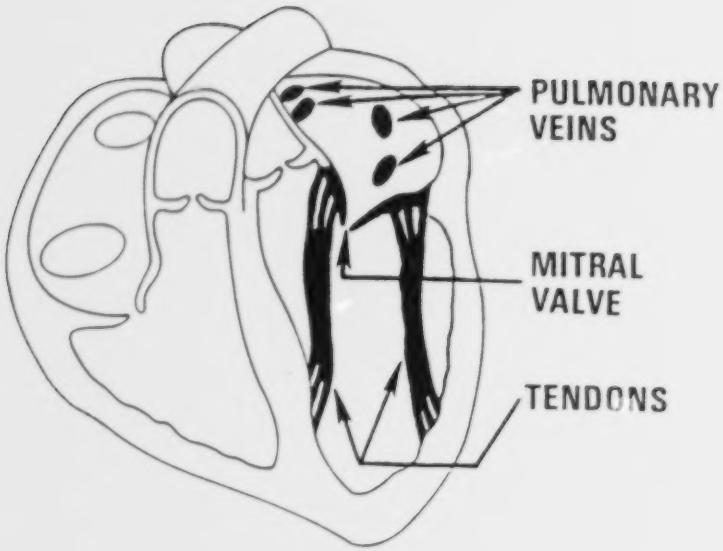
As blood from the body fills the right auricle, come of it begins to drip into the right ventricle immediately. The auricles and ventricles on each side of the heart communicate with each other through openings. The opening between the right auricle and right ventricle is called the tricuspid valve. This valve consists of three triangular flaps of thin, strong, fibrous tissue. These flaps permit the flow of blood into the right ventricle, but prevent it from flowing backward into the right auricle because the ends of the flaps are anchored to the floor of the right ventricle by slender tendons.



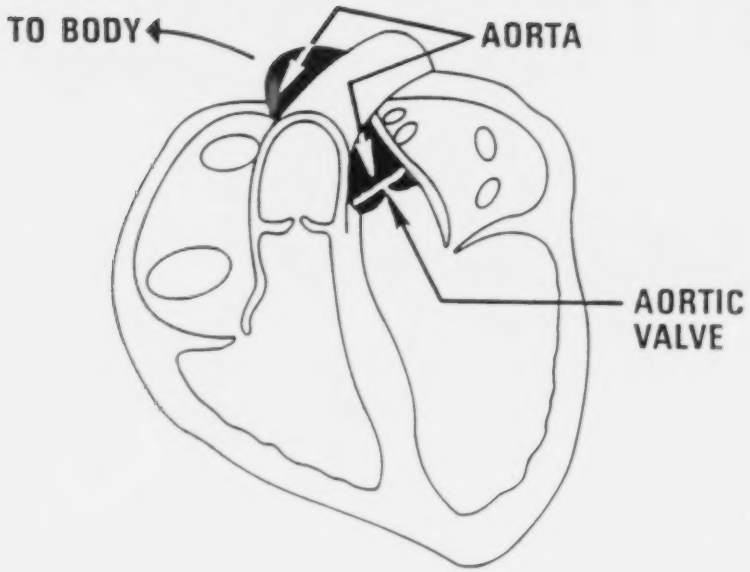
The three flaps act like swinging doors which open only in one direction. Thus, blood passes from the right auricle through the tricuspid valve into the right ventricle. As soon as the right ventricle is filled with blood, both ventricles begin to contract. The first effect of the pressure produced in the right ventricle is to force blood behind the flaps of the tricuspid valve. While the blood pressure behind the flaps brings the flaps together and prevents the flow of blood, the contraction of the right ventricle continues until the blood presses hard enough to open the pulmonary valve and to force the blood into the pulmonary artery. The pulmonary valve is located between the right ventricle and the pulmonary artery.



The pulmonary valve, like the tricuspid valve, consists of three flaps which fill with blood backing up in the pulmonary artery. as soon as the right ventricle begins to relax from its contraction, the pulmonary valve prevents blood from flowing back into the right ventricle from the pulmonary artery. The pulmonary valve opens only when the pressure in the right ventricle is greater than the pressure in the pulmonary artery, forcing the blood into the pulmonary artery. The pulmonary valve is composed of flaps or pockets, which the swollen pulmonary artery quickly fill with blood as soon as the right ventricle begins to relax from its contraction. The flaps or pockets of the valve are thus pressed together, and no blood flows back into the right ventricle.

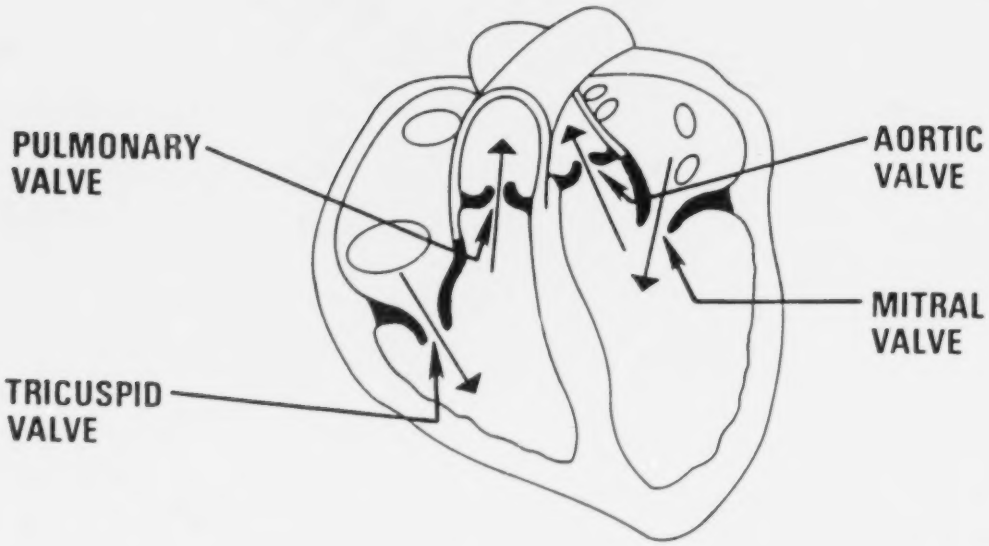


After the blood passes through the pulmonary valve it enters the pulmonary artery, from which it is carried up through the heart to both the left and right lungs where it is cleansed and oxygenated. Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle. Like the right auricle, the left auricle also contracts when it is full, squeezing blood through the mitral valve into the left ventricle. The mitral valve is located between the left auricle and the left ventricle.



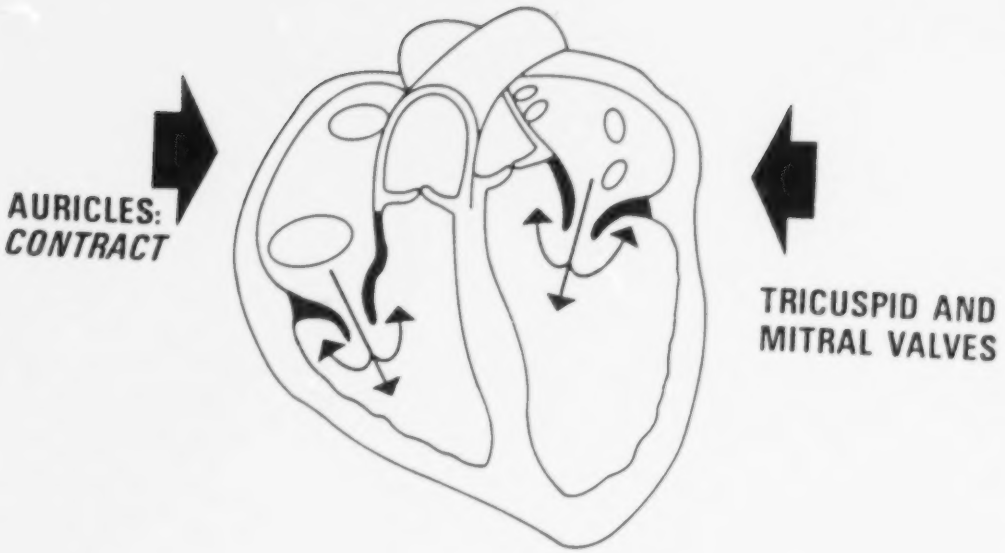
The mitral valve is similar in construction to the tricuspid valve. As the left ventricle contracts simultaneously with its mate, the right ventricle, it forces blood behind the flaps of the mitral valve, thereby closing the path back to the left auricle. The contraction of the left ventricle pumps the blood through the entire body. For this reason it is the largest, strongest, and most muscular section of the heart. When the left ventricle which is filled with blood contracts, the resulting pressure in the ventricle opens the aortic valve located in the mouth of the aorta.

The aorta is the large artery which carries the blood from the left ventricle.



The directional flow of blood in the heart is determined by valves which allow the blood to flow in only one direction.

Both auricles receive blood simultaneously through unguarded openings in the veins. The right auricle receives its blood through the superior and inferior vena cavas while the left auricle receives its blood through the pulmonary veins.



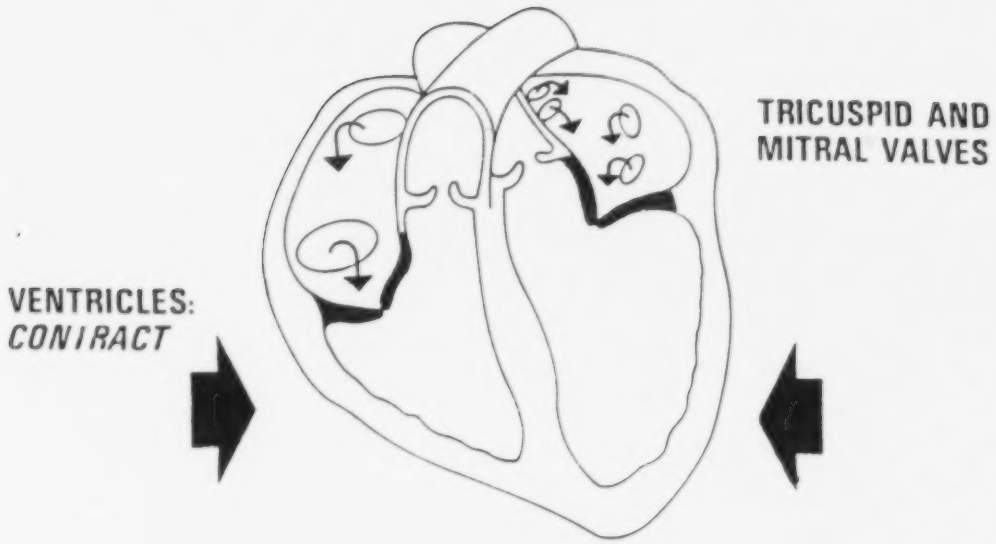
A wave of muscular contractions starts at the top of the heart and passes downward, simultaneously over both sides of the heart; that is, both auricles contract at the same time and then relax as the contraction passes down to the ventricles. When the auricles are caused to contract, they become small and pale, and in doing so the blood in their chambers is subjected to increased pressure which forces blood through both the tricuspid and mitral valves.

As the ventricles fill, eddies of the blood float the flaps on both the tricuspid and mitral valves out to a partly closed position.

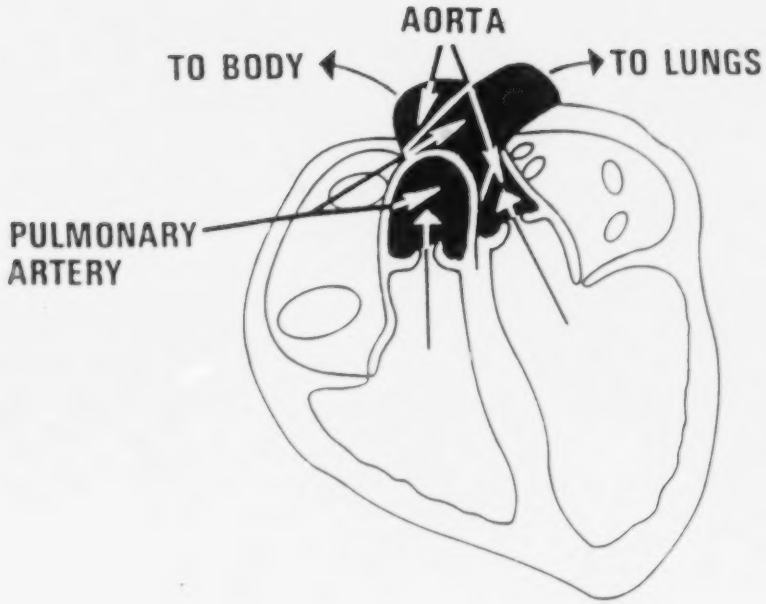
As the ventricle pressure becomes greater than that in the auricles, the valves are tightly closed and so prevent blood from being forced backward into the auricles.

While the auricles are relaxing from the contraction, blood flows into them from the veins as the contraction of the ventricles is initiated.

The instant that the contraction of the auricles has been completed, the ventricles are stimulated to contract; this contraction increases the pressure in the chambers, forcing the valves, both the tricuspid and mitral, completely shut.



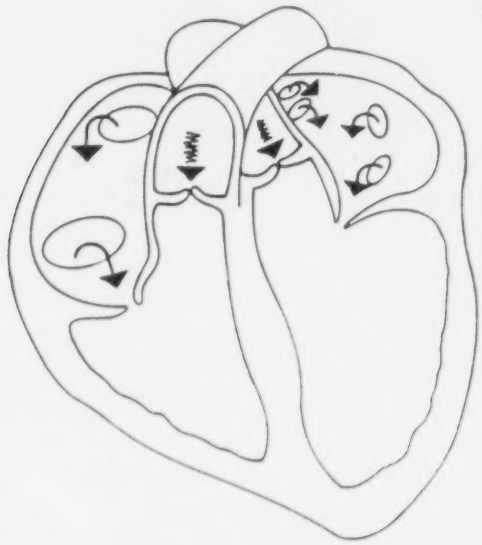
The pulmonary valve and the aortic valve, also called the semilunar valves, that guard the entrances to the pulmonary artery on the right and the aortic artery on the left are closed by the back pressure provided by the blood already in these vessels. When the ventricle pressure becomes greater than that in the exit vessels, the pulmonary and aortic valves open. Blood flows from the right ventricles into the pulmonary artery en route to the lungs and from the left ventricle into the aorta for distribution through the entire body.



Immediately following ejection of the blood into the arteries, the ventricles begin to relax; this lowers the pressure within their chambers, and the greater pressure in the arteries closes the semilunar valves. Pressure within the ventricles is sufficient, however, to maintain closure of the tricuspid and mitral valves against the already increasing auricle pressure.

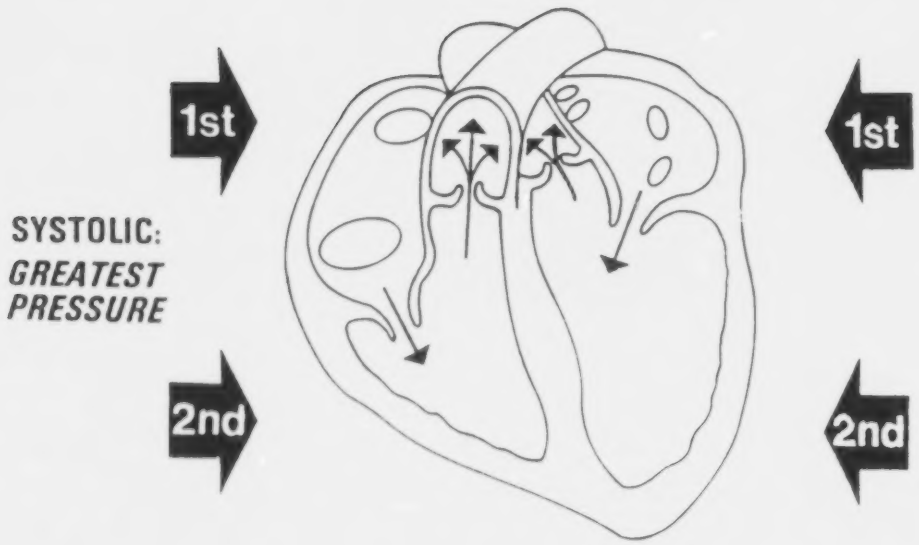
As the ventricles relax further, pressure within them decreases correspondingly, and the tricuspid and mitral valves are forced open by the increased auricle pressure caused by blood flowing into them from the veins. Therefore, before the next auricle contraction, blood is already flowing from the auricles into the ventricles because a greater blood pressure exists in the auricles than in the ventricles.

DIASTOLIC:
LOWEST PRESSURE



The relaxation of the ventricles, during which they are filled with blood, is called the diastolic phase.

The heart relaxes between beats in the diastolic phase. Blood flows into the heart filling both auricles. While the blood is flowing into the auricles, the recoil of the artery wall still maintains part of the pressure developed by the contraction of the ventricles. This is the time of the lowest pressure in the arteries or what is called diastolic pressure.



The contraction phase or systolic phase begins when the auricles contract. The blood forces its way through the mitral and tricuspid valves into the ventricles.

The ventricles contract and force the blood through semilunar valves, that is, the pulmonary and aortic valves.

After passing through the pulmonary and aortic valves, the blood enters the pulmonary and aortic arteries. The blood leaves the ventricles under terrific pressure and surges through the arteries with a force so great that it bulges their elastic walls. At this point, arterial blood pressure is the greatest; this pressure is called systolic pressure. The heart relaxes again and the tricuspid and mitral valves close. Blood flows into the auricles; the mitral and tricuspid valves are forced open, and the cycle begins again.

Try to picture in your mind the way the heart is positioned in the chest.

The human heart is a hollow, bluntly conical, muscular organ. Its pumping action provides the force that circulates the blood through the body. In the average adult, the heart is about five inches long and about two and one half inches thick. A man's heart weighs about eleven ounces and a woman's heart weighs about nine ounces.

The heart lies toward the front of the body and is in a slanting position between the lungs, immediately below the breastbone. The wide end points toward the right shoulder. The small end of the heart points downward to the front of the chest and toward the left. The lower portion of the heart is called the apex and is the part that you feel beating.

Try to picture in your mind the heart inside a sac with two walls. The pericardium is on the outer wall and the epicardium is on the inside wall.

In order to better comprehend the following instruction, it will be helpful to visualize a cross-section view of a human heart in a position such that you are facing the person. As you visualize it, the right side of the heart will be on the left side.

To understand the functioning of the heart you will need to be able to identify the parts of the heart. The heart is enclosed in a thin double-walled sac. The layer which forms the outer wall of the sac is called the pericardium. It is composed of a tough, transparent, elastic tissue. It protects the heart from rubbing against the lungs and the walls of the chest. The inner portion of the double walled sac is called the epicardium. It is attached to the heart muscle.

Try to picture in your mind the heart muscle--the myocardium--contracting and relaxing.

The heart muscle is called the myocardium; it controls the contraction and relaxation of the heart. The myocardium constitutes by far the greatest volume of the heart and its contraction is responsible for the propulsion of the blood throughout the body. The myocardium varies in thickness. For example, the myocardium forming the auricle walls is thin when compared to the thickness of the myocardium forming the ventricle walls.

The endocardium is the name given to the inside lining of the heart wall.

Try to picture in your mind the heart divided into two parts by the septum.

The human heart is really two pumps combined into a single organ which circulates blood to all parts of the body. The heart is divided longitudinally into two halves by the septum. The two halves may be compared to a block of two houses, which are independent of each other but have a common wall, the septum, between them.

Try to picture in your mind blood entering the upper chamber--the right auricle--from the body above heart level through the superior vena cava, and from rest of the body through the inferior vena cava.

Each half of the heart is divided into an upper chamber and a lower chamber; the upper chambers are called auricles and the lower chambers are called ventricles. Although there is no direct communication between the right and left sides of the heart, both sides function simultaneously. As was stated previously, the upper chambers on each side of the septum are auricles, and the lower chambers are called ventricles. Auricles have thin walls and act as receiving rooms for the blood while the ventricles below act as pumps, moving the blood away from the heart.

As you would view a cross-sectional diagram of the heart, blood enters the right auricle through veins. Only veins carry blood to the heart. The superior and inferior vena cavas are the two veins which deposit blood in the right auricle. There are no valves at the openings of these veins. The superior vena cava deposits blood into the right auricle from all body parts above heart level, for example, the head and the arms.

The other vein, the inferior vena cava, deposits blood into the right auricle from the trunk and legs–that is, from regions below the heart level.

Try to picture in your mind blood dripping through the three flaps of the tricuspid valve between the right auricle and the ventricle.

As blood from the body fills the right auricle, some of it begins to drip into the right ventricle immediately. The auricles and ventricles on each side of the heart communicate with each other through openings. The opening between the right auricle and right ventricle is called the tricuspid valve. This valve consists of three triangular flaps of thin, strong, fibrous tissue. These flaps permit the flow of blood into the right ventricle, but prevent it from flowing backward into the right auricle because the ends of the flaps are anchored to the floor of the right ventricle by slender tendons.

Try to picture in your mind blood in the right ventricle forcing open the pulmonary valve and rushing upward into the pulmonary artery.

The three flaps act like swinging doors which open only in one direction. Thus, blood passes from the right auricle through the tricuspid valve into the right ventricle. As soon as the right ventricle is filled with blood, both ventricles begin to contract. The first effect of the pressure produced in the right ventricle is to force blood behind the flaps of the tricuspid valve. While the blood pressure behind the flaps brings the flaps together and prevents the flow of blood, the contraction of the right ventricle continues until the blood presses hard enough to open the pulmonary valve and to force the blood into the pulmonary artery. The pulmonary valve is located between the right ventricle and the pulmonary artery.

Try to picture in your mind the pulmonary valve flaps pressing together when the pulmonary artery is full, preventing the blood from flowing backward into the right ventricle.

The pulmonary valve, like the tricuspid valve, consists of three flaps which fill with blood backing up in the pulmonary artery. as soon as the right ventricle begins to relax from its contraction, the pulmonary valve prevents blood from flowing back into the right ventricle from the pulmonary artery. The pulmonary valve opens only when the pressure in the right ventricle is greater than the pressure in the pulmonary artery, forcing the blood into the pulmonary artery. The pulmonary valve is composed of flaps or pockets, which the swollen pulmonary artery quickly fill with blood as soon as the right ventricle begins to relax from its contraction. The flaps or pockets of the valve are thus pressed together, and no blood flows back into the right ventricle.

Try to picture in your mind blood from the pulmonary veins filling the left auricle and then surging through the mitral valve into the left ventricle.

After the blood passes through the pulmonary valve it enters the pulmonary artery, from which it is carried up through the heart to both the left and right lungs where it is cleansed and oxygenated. Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle. Like the right auricle, the left auricle also contracts when it is full, squeezing blood through the mitral valve into the left ventricle. The mitral valve is located between the left auricle and the left ventricle.

Try to picture in your mind oxygenated blood from the strong left ventricle passing through the aortic valve into the aorta and then into the body.

The mitral valve is similar in construction to the tricuspid valve. As the left ventricle contracts simultaneously with its mate, the right ventricle, it forces blood behind the flaps of the mitral valve, thereby closing the path back to the left auricle. The contraction of the left ventricle pumps the blood through the entire body. For this reason it is the largest, strongest, and most muscular section of the heart. When the left ventricle which is filled with blood contracts, the resulting pressure in the ventricle opens the aortic valve located in the mouth of the aorta.

The aorta is the large artery which carries the blood from the left ventricle.

Try to picture in your mind blood from the body returning to the right auricle through the superior and inferior vena cavas.

The directional flow of blood in the heart is determined by valves which allow the blood to flow in only one direction.

Both auricles receive blood simultaneously through unguarded openings in the veins. The right auricle receives its blood through the superior and inferior vena cavas while the left auricle receives its blood through the pulmonary veins.

Try to picture in your mind the sequence of the heart's contractions: the auricles from at the top of the heart and then the ventricles at the bottom of the heart.

A wave of muscular contractions starts at the top of the heart and passes downward, simultaneously over both sides of the heart; that is, both auricles contract at the same time and then relax as the contraction passes down to the ventricles. When the auricles are caused to contract, they become small and pale, and in doing so the blood in their chambers is subjected to increased pressure which forces blood through both the tricuspid and mitral valves.

As the ventricles fill, eddies of the blood float the flaps on both the tricuspid and mitral valves out to a partly closed position.

As the ventricle pressure becomes greater than that in the auricles, the valves are tightly closed and so prevent blood from being forced backward into the auricles.

While the auricles are relaxing from the contraction, blood flows into them from the veins as the contraction of the ventricles is initiated.

The instant that the contraction of the auricles has been completed, the ventricles are stimulated to contract; this contraction increases the pressure in the chambers, forcing the valves, both the tricuspid and mitral, completely shut.

Try to picture in your mind a contraction of the ventricles which forces blood simultaneously through the semilunar valves into both the pulmonary artery and the aorta.

The pulmonary valve and the aortic valve, also called the semilunar valves, that guard the entrances to the pulmonary artery on the right and the aortic artery on the left are closed by the back pressure provided by the blood already in these vessels. When the ventricle pressure becomes greater than that in the exit vessels, the pulmonary and aortic valves open. Blood flows from the right ventricles into the pulmonary artery en route to the lungs and from the left ventricle into the aorta for distribution through the entire body.

Try to picture in your mind the high pressure in the aorta and ventricles keeping shut the tricuspid and mitral valves as blood begins to enter the auricles from the vena cavas as the auricles start to contract.

Immediately following ejection of the blood into the arteries, the ventricles begin to relax; this lowers the pressure within their chambers, and the greater pressure in the arteries closes the semilunar valves. Pressure within the ventricles is sufficient, however, to maintain closure of the tricuspid and mitral valves against the already increasing auricle pressure.

As the ventricles relax further, pressure within them decreases correspondingly, and the tricuspid and mitral valves are forced open by the increased auricle pressure caused by blood flowing into them from the veins. Therefore, before the next auricle contraction, blood is already flowing from the auricles into the ventricles because a greater blood pressure exists in the auricles than in the ventricles.

The cycle of the heartbeat consists of two parts

Try to picture in your mind the relaxation of the heart chambers as they begin to fill with blood--the auricles first then the ventricles--a relaxing that brings on low, diastolic pressure in the arteries.

The relaxation of the ventricles, during which they are filled with blood, is called the diastolic phase.

The heart relaxes between beats in the diastolic phase. Blood flows into the heart filling both auricles. While the blood is flowing into the auricles, the recoil of the artery wall still maintains part of the pressure developed by the contraction of the ventricles. This is the time of the lowest pressure in the arteries or what is called diastolic pressure.

Try to picture in your mind the systolic phase which has two contractions: auricles contracting from the top of the heart to force blood onto the ventricles and then the ventricles contracting to force blood away from the heart into the arteries under high pressure.

The contraction phase or systolic phase begins when the auricles contract. The blood forces its way through the mitral and tricuspid valves into the ventricles.

The ventricles contract and force the blood through semilunar valves, that is, the pulmonary and aortic valves.

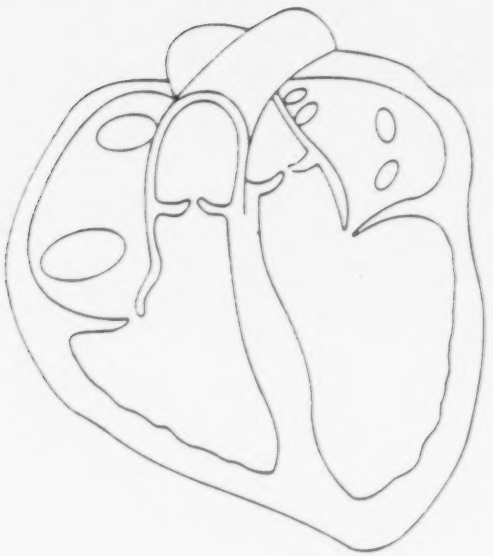
After passing through the pulmonary and aortic valves, the blood enters the pulmonary and aortic arteries. The blood leaves the ventricles under terrific pressure and surges through the arteries with a force so great that it bulges their elastic walls. At this point, arterial blood pressure is the greatest; this pressure is called systolic pressure. The heart relaxes again and the tricuspid and mitral valves close. Blood flows into the auricles; the mitral and tricuspid valves are forced open, and the cycle begins again.

The human heart is a hollow, bluntly conical, muscular organ. Its pumping action provides the force that circulates the blood through the body. In the average adult, the heart is about five inches long and about two and one half inches thick. A man's heart weighs about eleven ounces and a woman's heart weighs about nine ounces.

The heart lies toward the front of the body and is in a slanting position between the lungs, immediately below the breastbone. The wide end points toward the right shoulder. The small end of the heart points downward to the front of the chest and toward the left. The lower portion of the heart is called the apex and is the part that you feel beating.

Try to picture in your mind the way the heart is positioned in the chest.

RIGHT
SIDE

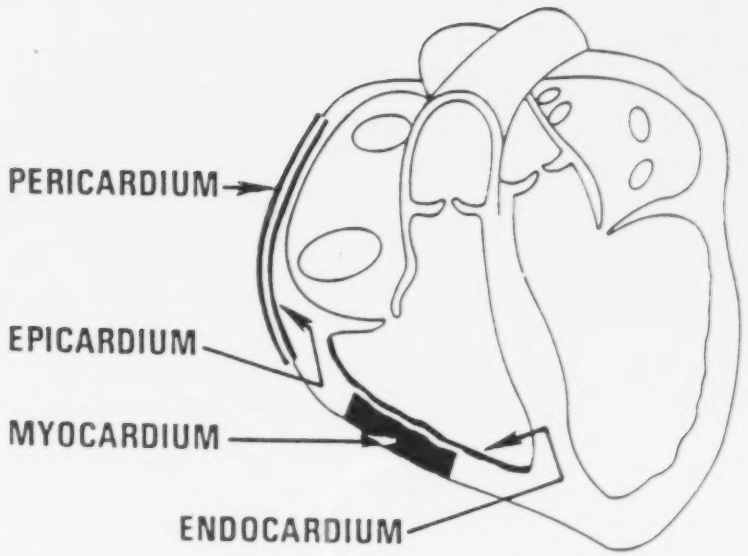


LEFT
SIDE

In order to better comprehend the following instruction. it will be helpful to visualize a cross-section view of a human heart in a position such that you are facing the person. As you visualize it. the right side of the heart will be on the left side.

To understand the functioning of the heart you will need to be able to identify the parts of the heart. The heart is enclosed in a thin double-walled sac. The layer which forms the outer wall of the sac is called the pericardium. It is composed of a tough, transparent. elastic tissue. It protects the heart from rubbing against the lungs and the walls of the chest. The inner portion of the double walled sac is called the epicardium. It is attached to the heart muscle.

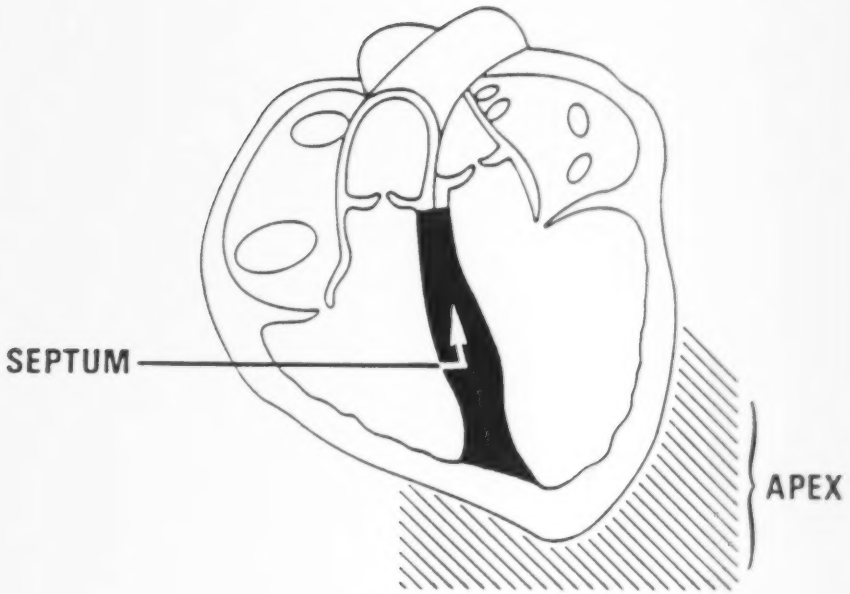
Try to picture in your mind the heart inside a sac with two walls. The pericardium is on the outer wall and the epicardium is on the inside wall.



The heart muscle is called the myocardium: it controls the contraction and relaxation of the heart. The myocardium constitutes by far the greatest volume of the heart and its contraction is responsible for the propulsion of the blood throughout the body. The myocardium varies in thickness. For example, the myocardium forming the auricle walls is thin when compared to the thickness of the myocardium forming the ventricle walls.

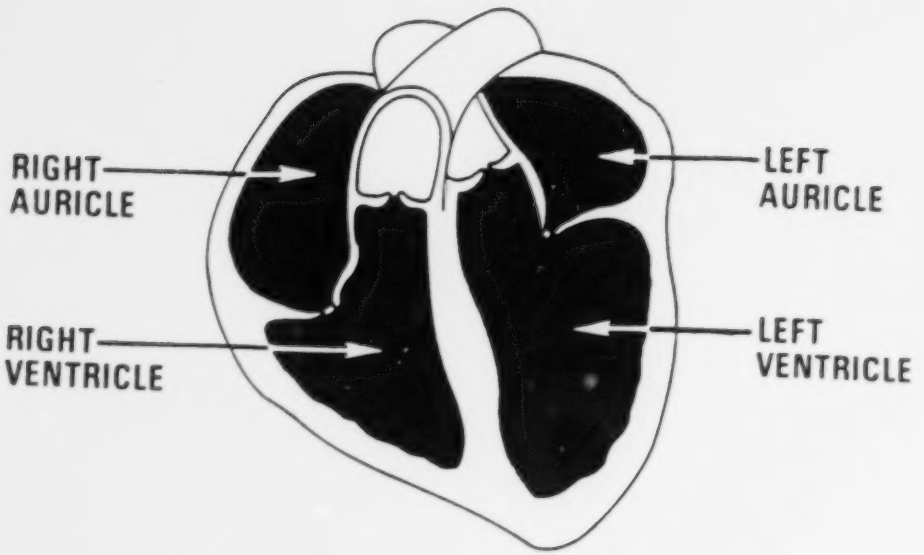
The endocardium is the name given to the inside lining of the heart wall.

Try to picture in your mind the heart muscle--the myocardium--contracting and relaxing.



The human heart is really two pumps combined into a single organ which circulates blood to all parts of the body. The heart is divided longitudinally into two halves by the septum. The two halves may be compared to a block of two houses, which are independent of each other but have a common wall, the septum, between them.

Try to picture in your mind the heart divided into two parts by the septum.

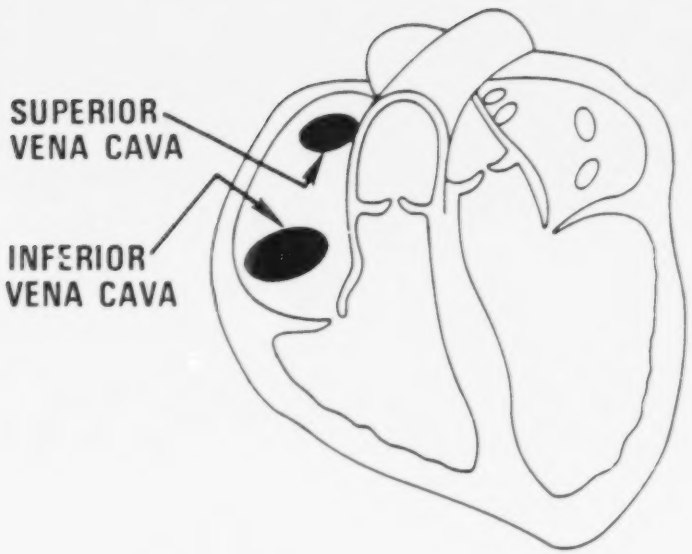


Each half of the heart is divided into an upper chamber and a lower chamber; the upper chambers are called auricles and the lower chambers are called ventricles. Although there is no direct communication between the right and left sides of the heart, both sides function simultaneously. As was stated previously, the upper chambers on each side of the septum are auricles, and the lower chambers are called ventricles. Auricles have thin walls and act as receiving rooms for the blood while the ventricles below act as pumps, moving the blood away from the heart.

As you would view a cross-sectional diagram of the heart, blood enters the right auricle through veins. Only veins carry blood to the heart. The superior and inferior vena cavas are the two veins which deposit blood in the right auricle. There are no valves at the openings of these veins. The superior vena cava deposits blood into the right auricle from all body parts above heart level, for example, the head and the arms.

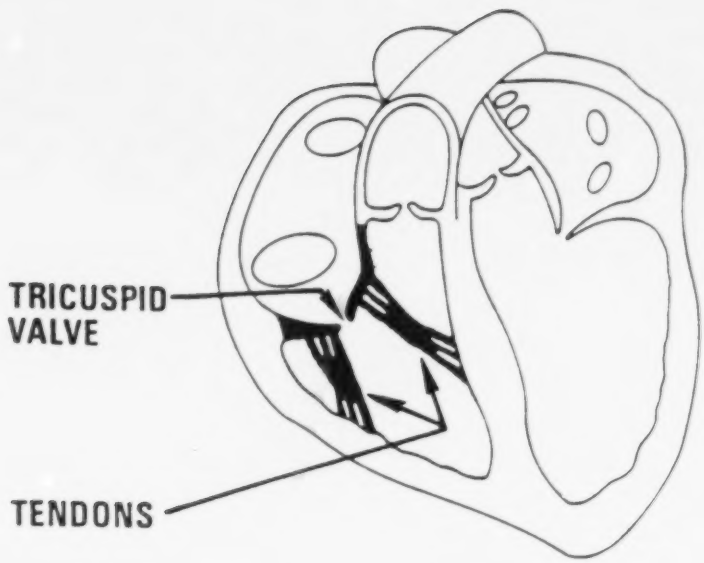
The other vein, the inferior vena cava, deposits blood into the right auricle from the trunk and legs–that is, from regions below the heart level.

> Try to picture in your mind blood entering the upper chamber--the right auricle--from the body above heart level through the superior vena cava, and from rest of the body through the inferior vena cava.



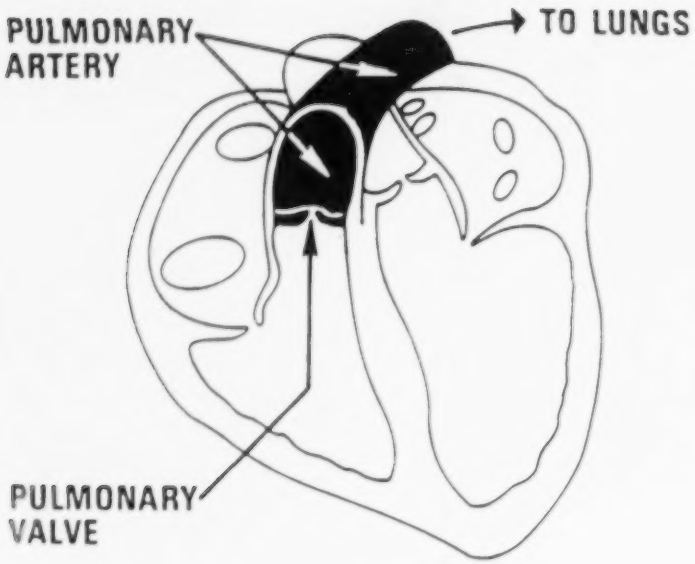
As blood from the body fills the right auricle, some of it begins to drip into the right ventricle immediately. The auricles and ventricles on each side of the heart communicate with each other through openings. The opening between the right auricle and right ventricle is called the tricuspid valve. This valve consists of three triangular flaps of thin, strong, fibrous tissue. These flaps permit the flow of blood into the right ventricle, but prevent it from flowing backward into the right auricle because the ends of the flaps are anchored to the floor of the right ventricle by slender tendons.

Try to picture in your mind blood dripping through the three flaps of the tricuspid valve between the right auricle and the ventricle.



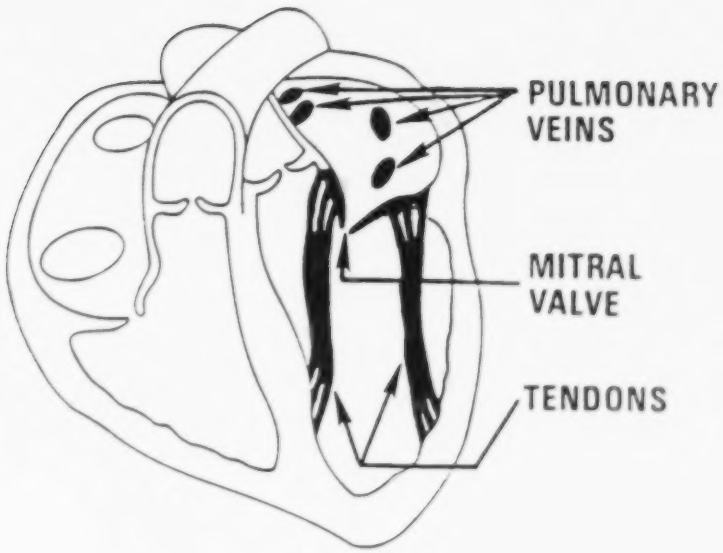
The three flaps act like swinging doors which open only in one direction. Thus, blood passes from the right auricle through the tricuspid valve into the right ventricle. As soon as the right ventricle is filled with blood, both ventricles begin to contract. The first effect of the pressure produced in the right ventricle is to force blood behind the flaps of the tricuspid valve. While the blood pressure behind the flaps brings the flaps together and prevents the flow of blood, the contraction of the right ventricle continues until the blood presses hard enough to open the pulmonary valve and to force the blood into the pulmonary artery. The pulmonary valve is located between the right ventricle and the pulmonary artery.

Try to picture in your mind blood in the right ventricle forcing open the pulmonary valve and rushing upward into the pulmonary artery.



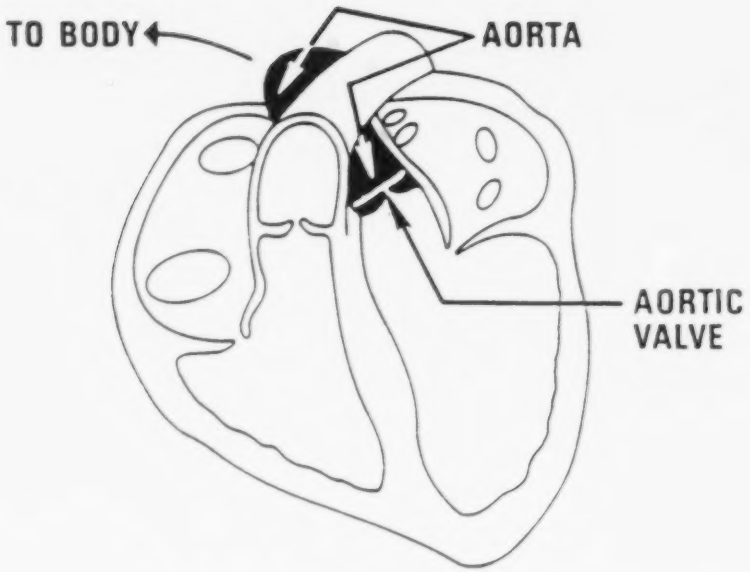
The pulmonary valve, like the tricuspid valve, consists of three flaps which fill with blood backing up in the pulmonary artery. as soon as the right ventricle begins to relax from its contraction, the pulmonary valve prevents blood from flowing back into the right ventricle from the pulmonary artery. The pulmonary valve opens only when the pressure in the right ventricle is greater than the pressure in the pulmonary artery, forcing the blood into the pulmonary artery. The pulmonary valve is composed of flaps or pockets, which the swollen pulmonary artery quickly fill with blood as soon as the right ventricle begins to relax from its contraction. The flaps or pockets of the valve are thus pressed together, and no blood flows back into the right ventricle.

Try to picture in your mind the pulmonary valve flaps pressing together when the pulmonary artery is full, preventing the blood from flowing backward into the right ventricle.



After the blood passes through the pulmonary valve it enters the pulmonary artery, from which it is carried up through the heart to both the left and right lungs where it is cleansed and oxygenated. Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle. Like the right auricle, the left auricle also contracts when it is full, squeezing blood through the mitral valve into the left ventricle. The mitral valve is located between the left auricle and the left ventricle.

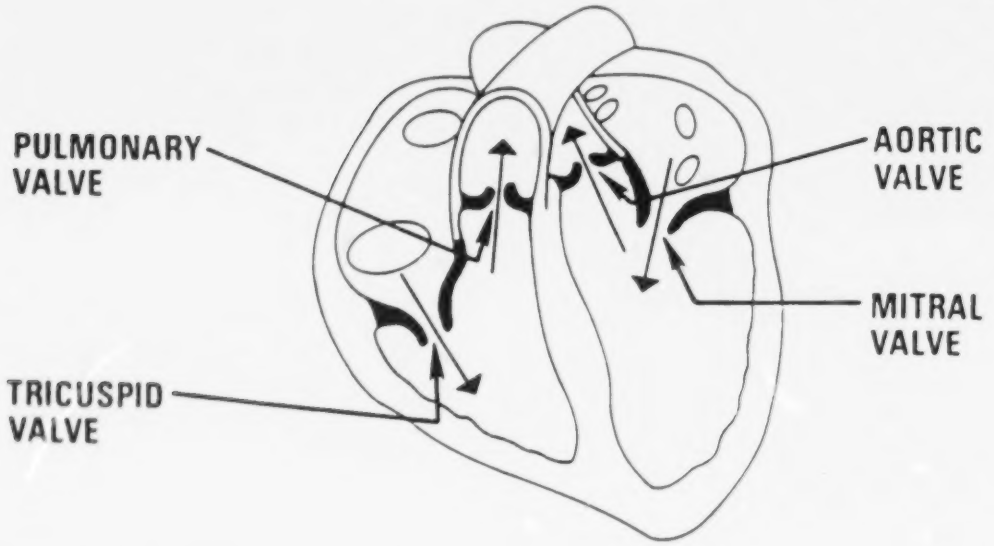
Try to picture in your mind blood from the pulmonary veins filling the left auricle and then surging through the mitral valve into the left ventricle.



The mitral valve is similar in construction to the tricuspid valve. As the left ventricle contracts simultaneously with its mate, the right ventricle, it forces blood behind the flaps of the mitral valve, thereby closing the path back to the left auricle. The contraction of the left ventricle pumps the blood through the entire body. For this reason it is the largest, strongest, and most muscular section of the heart. When the left ventricle which is filled with blood contracts, the resulting pressure in the ventricle opens the aortic valve located in the mouth of the aorta.

The aorta is the large artery which carries the blood from the left ventricle.

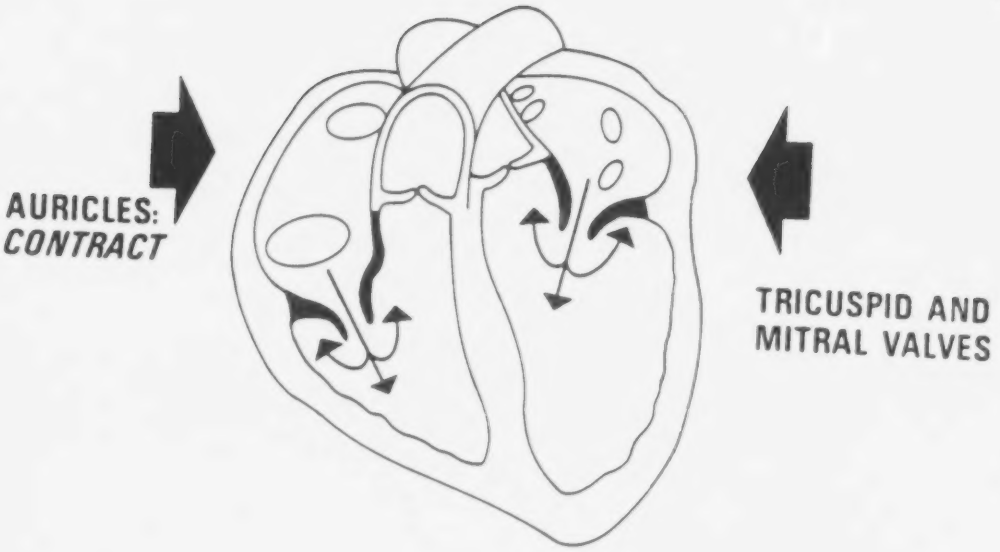
Try to picture in your mind oxygenated blood from the strong left ventricle passing through the aortic valve into the aorta and then into the body.



The directional flow of blood in the heart is determined by valves which allow the blood to flow in only one direction.

Both auricles receive blood simultaneously through unguarded openings in the veins. The right auricle receives its blood through the superior and inferior vena cavas while the left auricle receives its blood through the pulmonary veins.

Try to picture in your mind blood from the body returning to the right auricle through the superior and inferior vena cavas.



A wave of muscular contractions starts at the top of the heart and passes downward, simultaneously over both sides of the heart: that is, both auricles contract at the same time and then relax as the contraction passes down to the ventricles. When the auricles are caused to contract, they become small and pale, and in doing so the blood in their chambers is subjected to increased pressure which forces blood through both the tricuspid and mitral valves.

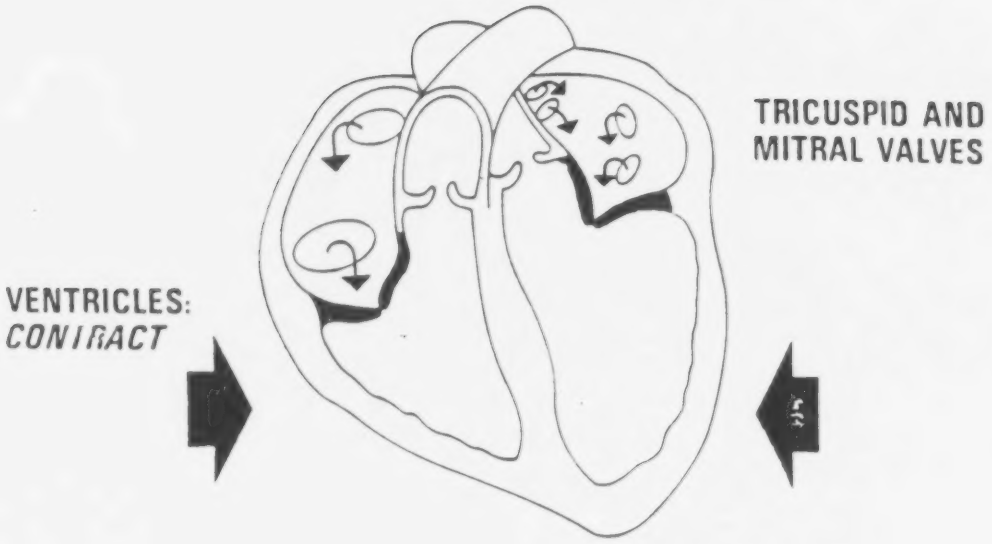
As the ventricles fill, eddies of the blood float the flaps on both the tricuspid and mitral valves out to a partly closed position.

As the ventricle pressure becomes greater than that in the auricles, the valves are tightly closed and so prevent blood from being forced backward into the auricles.

While the auricles are relaxing from the contraction, blood flows into them from the veins as the contraction of the ventricles is initiated.

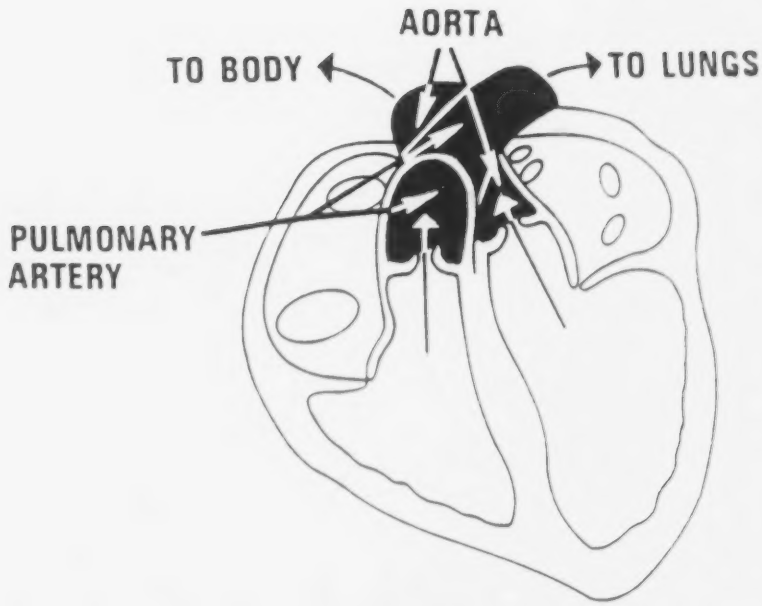
The instant that the contraction of the auricles has been completed, the ventricles are stimulated to contract; this contraction increases the pressure in the chambers, forcing the valves, both the tricuspid and mitral, completely shut.

Try to picture in your mind the sequence of the heart's contractions: the auricles from at the top of the heart and then the ventricles at the bottom of the heart.



The pulmonary valve and the aortic valve, also called the semilunar valves, that guard the entrances to the pulmonary artery on the right and the aortic artery on the left are closed by the back pressure provided by the blood already in these vessels. When the ventricle pressure becomes greater than that in the exit vessels, the pulmonary and aortic valves open. Blood flows from the right ventricles into the pulmonary artery en route to the lungs and from the left ventricle into the aorta for distribution through the entire body.

Try to picture in your mind a contraction of the ventricles which forces blood simultaneously through the semilunar valves into both the pulmonary artery and the aorta.

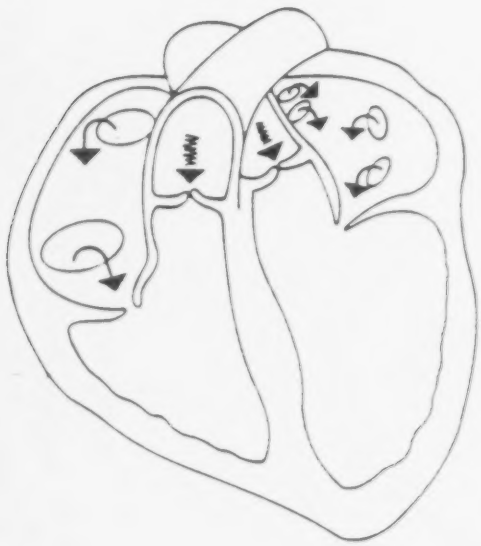


Immediately following ejection of the blood into the arteries, the ventricles begin to relax; this lowers the pressure within their chambers, and the greater pressure in the arteries closes the semilunar valves. Pressure within the ventricles is sufficient, however, to maintain closure of the tricuspid and mitral valves against the already increasing auricle pressure.

As the ventricles relax further, pressure within them decreases correspondingly, and the tricuspid and mitral valves are forced open by the increased auricle pressure caused by blood flowing into them from the veins. Therefore, before the next auricle contraction, blood is already flowing from the auricles into the ventricles because a greater blood pressure exists in the auricles than in the ventricles.

Try to picture in your mind the high pressure in the aorta and ventricles keeping shut the tricuspid and mitral valves as blood begins to enter the auricles from the vena cavas as the auricles start to contract.

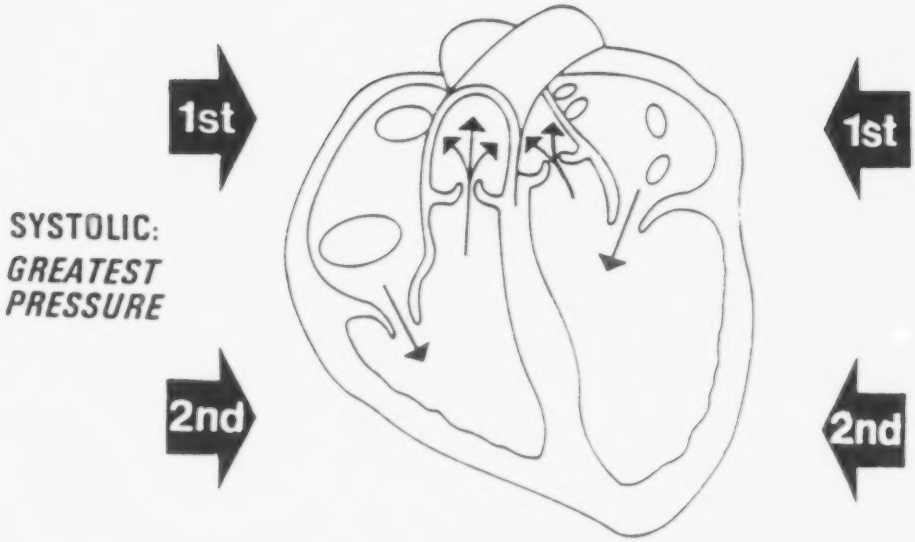
DIASTOLIC:
LOWEST PRESSURE



The relaxation of the ventricles, during which they are filled with blood, is called the diastolic phase.

The heart relaxes between beats in the diastolic phase. Blood flows into the heart filling both auricles. While the blood is flowing into the auricles, the recoil of the artery wall still maintains part of the pressure developed by the contraction of the ventricles. This is the time of the lowest pressure in the arteries or what is called diastolic pressure.

Try to picture in your mind the relaxation of the heart chambers as they begin to fill with blood--the auricles first then the ventricles--a relaxing that brings on low, diastolic pressure in the arteries.



The contraction phase or systolic phase begins when the auricles contract. The blood forces its way through the mitral and tricuspid valves into the ventricles.

The ventricles contract and force the blood through semilunar valves, that is, the pulmonary and aortic valves.

After passing through the pulmonary and aortic valves, the blood enters the pulmonary and aortic arteries. The blood leaves the ventricles under terrific pressure and surges through the arteries with a force so great that it bulges their elastic walls. At this point, arterial blood pressure is the greatest; this pressure is called systolic pressure. The heart relaxes again and the tricuspid and mitral valves close. Blood flows into the auricles; the mitral and tricuspid valves are forced open, and the cycle begins again.

Try to picture in your mind the systolic phase which has two contractions: auricles contracting from the top of the heart to force blood onto the ventricles and then the ventricles contracting to force blood away from the heart into the arteries under high pressure.

Appendix E

CRITERION-REFERENCED POSTTESTS

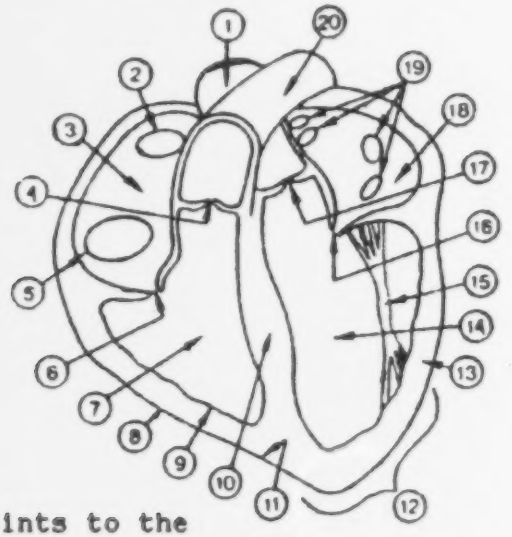
Drawing Test

Directions: Draw a simple line drawing of a heart and place the corresponding number of the 20 identified parts (on the list below) in the correct location on the drawing.

1. Superior Vena Cava
2. Aorta
3. Tricuspid Valve
4. Pulmonary Veins
5. Septum
6. Epicardium
7. Aortic Valve
8. Pulmonary Valve
9. Inferior Vena Cava
10. Pulmonary Artery
11. Myocardium
12. Endocardium
13. Mitral Valve
14. Right Auricle
15. Right Ventricle
16. Left Auricle
17. Left Ventricle
18. Apex
19. Tendons
20. Pericardium

Identification Test

Mark the time started on the time sheet.
Directions: Select the answer you feel best identifies the part of the heart indicated by the numbered arrows and mark the corresponding letter on the answer sheet. All answers must be recorded with a number two pencil.



1. Arrow number one (1) points to the
   a. septum
   b. aorta
   c. pulmonary artery
   d. pulmonary vein
   e. none of these

2. Arrow number two (2) points to the
   a. superior vena cava
   b. inferior vena cava
   c. pulmonary artery
   d. tricuspid valve
   e. aorta

3. Arrow number three (3) points to the
   a. right auricle
   b. right ventricle
   c. left auricle
   d. left auricle
   e. heart muscle

4. Arrow number four (4) points to the
   a. Pulmonary valve
   b. pulmonary vein
   c. aortic vein
   d. tricuspid valve
   e. mitral valve

5. Arrow number five (5) points to the
   a. aorta
   b. pulmonary artery
   c. superior vena cava
   d. inferior vena cava
   e. pulmonary vein

6. Arrow number six (6) points to the
   a. aortic valve
   b. pulmonary valve
   c. mitral valve
   d. tricuspid valve
   e. semi-lumar valve

7. Arrow number seven (7) points to the
   a. left ventricle
   b. right ventricle
   c. right aurucle
   d. left auricle
   e. vascular space

8. Arrow number eight (8) points to the
   a. myocardium
   b. ectoderm
   c. pericardium
   d. endocardium
   e. epicardium

9. Arrow number nine (9) points to the
   a. endocardium
   b. myocardium
   c. pericardium
   d. ectocardium
   e. septum

10. Arrow number ten (10) points to the
   a. endocardium
   b. pericardium
   c. septum
   d. myocardium
   e. aortic base

11. Arrow number eleven (11) points to the
   a. epicardium
   b. pericardium
   c. endocardium
   d. myocardium
   e. none of these

12. Arrow number twelve (12) points to the
    a. pericardium
    b. myocardium
    c. endocardium
    d. endoderm
    e. apex

13. Arrow number thirteen (13) points to the
    a. pericardium
    b. endocardium
    c. ectocardium
    d. ectoderm
    e. myocardium

14. Arrow number fourteen (14) points to the
    a. right ventricle
    b. left ventricle
    c. left auricle
    d. right auricle
    e. apex

15. Arrow number fifteen (15) points to the
    a. pulmonary veins
    b. tendons
    c. aortas
    d. pericardium
    e. none of these

16. Arrow number sixteen (16) points to the
    a. venic valve
    b. pulmonary artery
    c. tricuspid valve
    d. mitral valve
    e. aortic valve

17. Arrow number seventeen (17) points to the
    a. superior vena cava
    b. tricuspid valve
    c. aortic valve
    d. pulmonary valve
    e. mitral valve

18. Arrow number eighteen (18) points to the
    a. right auricle
    b. right ventricle
    c. left auricle
    d. left ventricle
    e. semi-lunar valves

19. Arrow number nineteen (19) points to the
    a. inferior vena cava
    b. superior vena cava
    c. aortas
    d. pulmonary veins
    e. pulmonary artery

20. Arrow number twenty (20) points to the
    a. inferior vena cava
    b. aorta
    c. pulmonary artery
    d. septum
    e. superior vena cava

Terminology Test

21. _____ is (are) the thickest walled chambers of the heart
    a. auricles
    b. myocardium
    c. ventricles
    d. pericardium
    e. endocardium

22. The contraction of the heart takes place during the ____ phase.
    a. systolic
    b. sympathetic
    c. diastolic
    d. parasympathetic
    e. sympatric

23. The lowest blood pressure in the arteries occurrs during the _____ phase.
    a. sympatric
    b. sympathetic
    c. diastolic
    d. systolic
    e. parasympathetic

24. Blood from the right ventricle goes to the lungs through the _____.
    a. tricuspid valve
    b. aortic artery
    c. pulmonary artery
    d. pulmonary veins
    e. superior vena cava

25. The _____ is (are) the strongest sections of the heart.
   a. left ventricle
   b. aorta
   c. septum
   d. right ventricle
   e. pulmonary artery

26. When blood returns to the heart from the lungs, it enters the _____.
   a. left auricle
   b. pulmonary valve
   c. left ventricle
   d. right ventricle
   e. pulmonary artery

27. Vessels that allow the blood to flow from the heart are called _____.
   a. veins
   b. arteries
   c. apex
   d. tendons
   e. valves

28. Blood passes from the left ventricle out of the aortic valve to the _____.
   a. lungs
   b. body
   c. aorta
   d. pulmonary artery
   e. left auricle

29. The chamber of the heart which pumps oxygenated blood to all parts of the body is the _____.
   a. right auricle
   b. left auricle
   c. aorta
   d. left ventricle
   e. right ventricle

30. The _____ is another name for the part of the heart called the heart muscle.
   a. apex
   b. epicardium
   c. endocardium
   d. myocardium
   e. septum

31. _____ is (are) the part(s) of the heart which controls its contraction and relaxation.
    a. myocardium
    b. endocardium
    c. ventricles
    d. auricles
    e. septum

32. The _____ is the name given to the inside lining of the heart wall.
    a. epicardium
    b. endocardium
    c. pericardium
    d. myocardium
    e. septum

33. Blood from the body enters the heart through the _____.
    a. aortic artery
    b. pulmonary veins
    c. pulmonary artery
    d. superior and inferior vena cavas
    e. superior vena cava only

34. The membrane which borders on the inside lining of the pericardium and is the connected to the heart muscle is called the _____.
    a. exotoxin
    b. epicardium
    c. endocardium
    d. myocardium
    e. ectocardium

35. The ____ allow(s) blood to travel in one direction only.
    a. septum
    b. valves
    c. arteries
    d. veins
    e. tendons

36. The ____ is the common opening between the right auricle and the right ventricle.
    a. mitral valve
    b. tricuspid valve
    c. semi-lunar valve
    d. pulmonary valve
    e. aortic valve

37. The _____ is a triangular flapped valve between the left auricle and the left ventricle.
   a. aortic valve
   b. pulmonary valve
   c. septic valve
   d. tricuspid valve
   e. mitral valve

38. The semi-lunar valves are located at the entrance to the ____.
   a. pulmonary veins
   b. superior and inferior vena cavas
   c. pulmonary and aortic arteries
   d. mitral and tricuspid valves
   e. ventricles

39. The outside covering of the heart is called the _____.
   a. endocardium
   b. epicardium
   c. pericardium
   d. myocardium
   e. none of these

40. Immediately before entering the aorta, blood must pass through the _____.
   a. left ventricle
   b. mitral valve
   c. lungs
   d. superior vena cava
   e. aortic valve

Comprehension Test

41. Which valve is most like the tricuspid in function?
   a. pulmonary
   b. aortic
   c. mitral
   d. superior vena cava

42. When blood is being forced out the right ventricle, in which position is the tricuspid valve?
   a. beginning to open
   b. beginning to close
   c. open
   d. closed

43. When blood is being forced out the aorta, it is also being forced out the
   a. pulmonary veins
   b. pulmonary artery
   c. superior vena cava
   d. cardiac artery

44. The contraction impulse in the heart starts in
    a. the right auricle
    b. both ventricles simultaneously
    c. both auricles simultaneously
    d. the arteries

45. In the diastolic phase, the ventricles are
    a. contracting, full of blood
    b. contracting, partially full of blood
    c. relaxing, full of blood
    d. relaxing, partly full of blood

46. During the first contraction of the systolic phase, in what position will the mitral valve be?
    a. beginning to open
    b. open
    c. beginning to close
    d. closed

47. During the second contraction of the systolic phase, blood is being forced away from the heart through the
    a. pulmonary and aortic arteries
    b. superior and inferior vena cava
    c. tricuspid and mitral valves
    d. pulmonary valves

48. When blood is entering through the vena cavas, it is also entering through the
    a. mitral valve
    b. pulmonary veins
    c. pulmonary artery
    d. aorta

49. When the heart contracts, the
    a. auricles and ventricles contract simultaneously
    b. ventricles contract first, then the auricles
    c. right side contracts first, then the left side
    d. auricles contract first, then the ventricles

50. While blood from the body is entering the superior vena cava, blood from the body is also entering through the
    a. pulmonary veins
    b. aorta
    c. inferior vena cava
    d. pulmonary artery

51. When blood leaves the heart through the pulmonary artery, it is also simultaneously leaving the heart through the
    a. tricuspid valve
    b. pulmonary veins
    c. aorta
    d. pulmonary valve

52. When the pressure in the right ventricle is superior to that in the pulmonary artery, in what position is the tricuspid valve?
    a. closed
    b. open
    c. beginning to close
    d. confined by pressure from the right auricle

53. When the ventricles contract, blood is forced out the
    a. superior and inferior vena cavas
    b. pulmonary veins
    c. tricuspid and mitral valves
    d. pulmonary and aortic valves

54. Blood leaving the heart through the aorta had left the heart previously through the
    a. vena cavas
    b. pulmonary veins
    c. pulmonary artery
    d. tricuslid and mitral valves

55. When blood in the aorta is exerting a superior pressure on the aortic valve, what is the position of the mitral valve?
    a. Closed
    b. open
    c. beginning to open
    d. confined by pressure from the right ventricle

56. When the tricuspid and mitral valves are forced shut, in what position is the pulmonary valve?
    a. closed
    b. beginning to open
    c. open
    d. beginning to close

57. During the second contraction of the systolic phase, in what position is the aortic valve?
    a. fully open
    b. partially open
    c. partially closed
    d. fully closed

58. Blood is being forced out the auricles simultaneously as blood is
    a. entering the vena cavas
    b. being forced out the pulmonary and aortic valves
    c. passes through the tricuspid and mitral valves
    d. being forces through the pulmonary artery

59. If the aortic valve is completely open, the
    a. second contraction of the systolic phase of the heart is occurring
    b. diastolic phase of the heart is occurring
    c. the tricuspid and mitral valves are completely open
    d. blood is rushing into the right and left ventricles

60. When the heart relaxes, the
    a. auricles relax first
    b. right side relaxes first, then the left side
    c. left side relaxes first,then the right side
    d. ventricles relax first, then the auricles

Mark time completed on sheet.
Hand in all materials to the investigator.

Appendix F

RELIABILITY COEFFICIENTS

Reliability Coefficients

Posttest Reliability
Kuder-Richardson Coefficients

	Identification	Terminology	Comprehension
Group T	0.851	0.834	0.71
Group TV	0.828	0.851	0.792
Group TI	0.761	0.891	0.803
Group TVI	0.864	0.81	0.84

	Total Criterion	Drawing
Group T	0.927	0.839
Group TV	0.933	0.889
Group TI	0.915	0.746
Group TVI	0.932	0.849

Questionnaire Reliability
Coefficient Alpha Values

Group T	0.576
Group TV	-0.04
Group TI	0.495
Group TVI	0.435

Appendix G

DESCRIPTIVE STATISTICS OF DEPENDENT MEASURES

Descriptive Statistics of

Total Criterion and Identification

Posttest Scores

Total Criterion

	Visual Illustrations	No Visual Illustrations	Row Values
Imagery Instructions	M = 37.47 SD= 10.75	M = 30.38 SD= 11.45	M = 35.13 SD= 10.93
No Imagery Instructions	M = 35.69 SD= 10.21	M = 34.00 SD= 12.04	M = 36.02 SD= 10.73
Column Values	M = 36.88 SD= 10.46	M = 33.27 SD= 11.71	M = 35.57 SD= 10.79

Identification

	Visual Illustrations	No Visual Illustrations	Row Values
Imagery Instructions	M = 14.43 SD= 4.19	M = 10.61 SD= 3.74	M = 12.52 SD= 4.2
No Imagery Instructions	M = 13.79 SD= 3.72	M = 12.54 SD= 4.2	M = 13.16 SD= 3.98
Column Values	M = 14.11 SD= 3.73	M = 11.57 SD= 4.06	M = 12.84 SD= 4.08

Descriptive Statistics of

Accretion Time Measures and

Drawing Posttest Scores

Accretion Time

	Visual Illustrations	No Visual Illustrations	Row Values
Imagery Instructions	M = 937.18 SD= 335.85	M = 834.43 SD= 192.91	M = 885.8 SD= 276.28
No Imagery Instructions	M = 764.57 SD= 297.68	M = 625.25 SD= 140.37	M = 694.91 SD= 241.07
Column Values	M = 850.88 SD= 326.28	M = 729.84 SD= 177.68	M = 790.36 SD= 275.33

Drawing

	Visual Illustrations	No Visual Illustrations	Row Values
Imagery Instructions	M = 16.00 SD= 3.22	M = 11.29 SD= 3.55	M = 13.64 SD= 3.31
No Imagery Instructions	M = 14.25 SD= 4.54	M = 9.75 SD= 4.41	M = 12.00 SD= 4.48
Column Values	M = 15.13 SD= 4.00	M = 10.52 SD= 4.04	M = 12.82 SD= 4.02